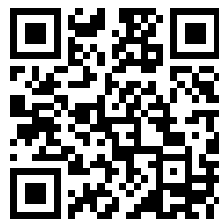


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DEPARTMENT OF COMMERCE

**CIRCULAR**

OF THE

**BUREAU OF STANDARDS**

S. W. STRATTON, DIRECTOR

No. 121

**CONSTRUCTION AND OPERATION OF A  
TWO-CIRCUIT RADIO RECEIVING  
EQUIPMENT WITH CRYSTAL  
DETECTOR**

JULY 17, 1922



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# CONSTRUCTION AND OPERATION OF A TWO-CIRCUIT RADIO RECEIVING EQUIPMENT WITH CRYSTAL DETECTOR

## ABSTRACT

The apparatus used for the reception of radio messages may be a homemade affair, very simple and inexpensive, or may be elaborate and expensive. All that is necessary for receiving radio messages is a device for collecting power from the incoming radio waves, a suitable circuit adjusted or "tuned" electrically to the frequency of the incoming waves, and apparatus for changing the received power into audible sounds.

The device for collecting power from the incoming waves is the "antenna." To the antenna is connected the "receiving set." The receiving set may be adjusted or tuned to the frequency of the incoming wave by varying the inductances and the capacity which are included in the circuits.

This Circular describes the construction and operation of a homemade and inexpensive two-circuit radio receiving set employing a crystal detector. The cost of the materials need not exceed \$15. The descriptions are meant to be so elementary and explicit that the set may be constructed by persons having no previous experience with radio.

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## 1. INTRODUCTION

This Circular<sup>1</sup> describes the construction and operation of a simple radio receiving set which will receive messages from high-power radiotelephone stations over a distance of about 75 miles

<sup>1</sup> This is the second of a series of circulars on the construction of radio receiving equipments. Those who expect to construct the set herein described should first obtain a copy of Bureau of Standards Circular No. 120, Construction and Operation of a Simple Homemade Radio Receiving Outfit, by writing the Superintendent of Documents, Government Printing Office, Washington, D. C., and inclosing 5 cents. Cash may be sent at risk of sender or remittance may be made by money order. Stamps will not be accepted. Circular No. 120 was originally issued in mimeographed form as Bureau of Standards Letter Circular No. 43.

Persons who desire an elementary text covering the principles and practice of radio communication should purchase a copy of The Principles Underlying Radio Communication, Signal Corps Radio Communication Pamphlet No. 40. This is a book of 600 pages and contains 300 illustrations, including circuit diagrams. Price, \$1 per copy. Orders should be sent to the Superintendent of Documents.

A much more elementary discussion of radio principles may be found in Signal Corps Radio Communication Pamphlet No. 1, Elementary Principles of Radio Telegraphy. Price, 10¢. An elementary discussion of electrical principles may be found in Signal Corps Training Pamphlet No. 1, Elementary Electricity. Price, 15¢. Orders should be sent to the Superintendent of Documents.



and from medium-power stations over a distance of about 10 miles. The complete equipment will respond to about the same wave frequencies (wave lengths) as the equipment described in Circular No. 120. Besides receiving over greater distances, another advantage of this set is that it is more "selective," which means that it is easier to distinguish the message from one of two radio transmitting stations when both of the transmitting stations are using wave frequencies (wave lengths) that are nearly the same. This greater selectivity is brought about through the use of two complete electric circuits, both of which are tuned to the incoming waves. This is in contrast to the single-circuit equipment, as described in the first pamphlet.

The total cost of this equipment can be kept down to about \$15. Most of the equipment mentioned in Circular No. 120 can also be used with this set, and the cost of the additional apparatus will be about \$5.

This publication describes simple apparatus of satisfactory performance without reference to the possible existence of any patents which might cover parts of the apparatus. Apparatus in general similar to that described can be purchased from responsible manufacturers whose announcements can be found in current radio periodicals.

## 2. ESSENTIAL PARTS OF RECEIVING STATION

ANTENNA, LIGHTNING SWITCH, GROUND CONNECTIONS, AND TELEPHONE RECEIVERS.—These are completely described in Circular No. 120. The other essential part of the equipment is the receiving set, which is made up of the following parts:

COUPLER (LEFT HALF OF FIG. 1).—This is composed of a fixed section and a movable section. The fixed section is made up of the coil tube *P*, the upright support *J*, the contact panel *K*, and the base *B*. The movable section is composed of the coil tube *S*, the supporting contact panel *M*, and the base *L*. The movable section is so arranged that coil tube *S* slips inside of the coil tube *P* when *M* is pushed to the left. The coil tubes are made by winding wire on cardboard tubing.

This Circular tells how to construct a coupler. It is of course possible to purchase a coupler of the type here described at almost any store which handles radio supplies. Another type of coupler which may be employed (called a "vario-coupler") has a rotating spherical coil inside the cylindrical coil. In purchasing any coupling device care should be taken to select one which will

operate satisfactorily with the condenser available, so that the receiving set may be tuned to the wave frequencies (wave lengths) desired.

**VARIABLE CONDENSER (C, FIGS. 1 AND 2).**—The variable air condenser should have a maximum capacity rating between 0.0004 and 0.0005 microfarads (400 to 500 micromicrofarads).

**CRYSTAL DETECTOR (D, FIGS. 1 AND 2).**—This is essentially the same crystal detector as was described in Circular No. 120 except that a few improvements have been made in its construction.

**ACCESSORIES.**—Under the heading of accessory equipment may be listed binding posts, switch arms, switch contacts, test buzzer, dry battery, and boards on which to mount the complete apparatus. The binding posts, switch arms, and switch contacts may be purchased from electrical dealers who handle such goods or they may be readily improvised at home. The pieces of wood on which the equipment is mounted may be obtained from a dry packing box.

### 3. DETAILS OF COUPLER CONSTRUCTION

**MOVABLE COIL TUBE, COIL-TUBE SUPPORT AND BASE (S, M, AND L, FIG. 1).**—The coil tube *S* is a piece of cardboard tubing  $3\frac{3}{8}$  inches in diameter and 4 inches long. A round cardboard table-salt box which can be obtained at a grocery store is about  $3\frac{3}{8}$  inches in diameter and can be used for this purpose. One of the cardboard ends or caps should be securely glued to the box. This tube is wound with No. 24 (or No. 26) double cotton-covered copper wire.

The method of winding the wire is much the same as described in Circular No. 120. Punch two holes in the tube three-eighths inch from the open end, as shown at *R*, Figure 2. Weave the end of the wire through these holes so that it is firmly anchored and has one end extending about 10 inches inside the tube. Punch a hole *F* about five-eighths inch from the other end (which has the cardboard cover secured to it) in line with the holes punched at *R*. Draw the free end of the wire through the inside of the tube and thread it out through the hole at *F*. Now wind on 10 turns of wire (starting from *R*) and take off a 6-inch twisted tap, as described in Circular No. 120. Hold the turns tight and punch a hole *B* directly underneath this tap. Insert the end of the tap into the hole and pull it through the inside of the tube so that the turns are held in place. The hole for this tap should be slightly staggered from the first two holes (*R*) which were punched.

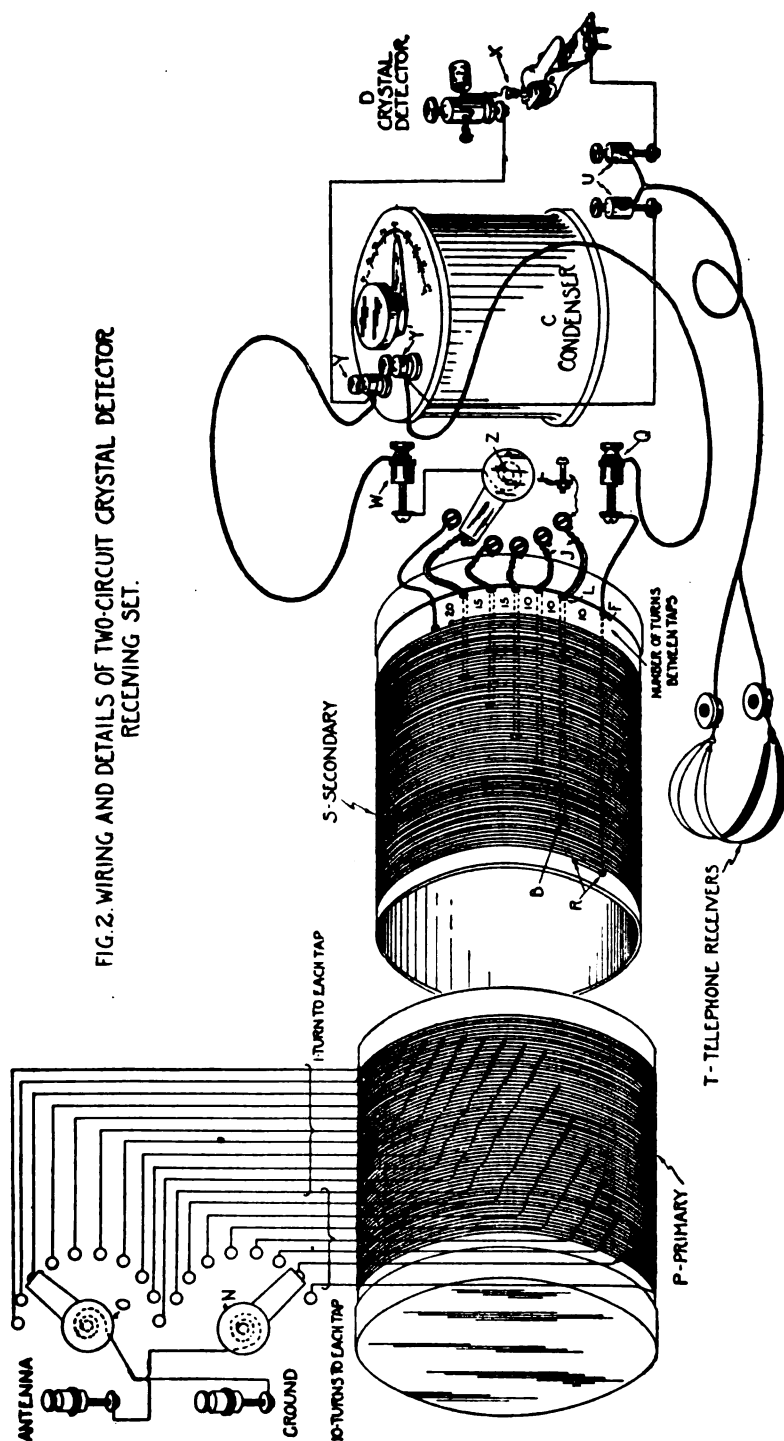


FIG. 2. WIRING AND DETAILS OF TWO-CIRCUIT CRYSTAL DETECTOR RECEIVING SET.

Punch another hole (*L*) five-eighths inch from the other end of the tube and in line with hole *B*. Thread the twisted tap out through this hole and pull it tight. Wind on 10 more turns and bring out another twisted tap; then 10 more turns and another tap; 15 turns and another tap; 15 more turns and another tap. Finally, wind on 20 more turns and bring out the free end of the wire in the same manner as the taps were brought out. The tube now has 80 turns of wire wound on it, and there are five twisted taps and 2 single wires projecting through the row of holes at the closed end of the tube. The position of the wires inside the coil tube is shown in Figure 2 by the dotted lines.

The contact panel *M* (Fig. 1) which supports the coil tube is a piece of dry wood  $5\frac{1}{2}$  inches high, 4 inches wide, and one-half inch thick. The contacts, switch arm and knob, and binding posts are described in Circular No. 120. The end of the switch arm should be wide enough so that it will not drop between the contact points, but still narrow enough so that it may be set to touch only a single contact at a time. Having located the hole for the switch-arm bolt, the switch arm should be placed in position and the knob rotated in such a manner that the end of the contact arm will describe an arc upon which the contact points are to be placed. The holes for the contacts should next be drilled, the spacing depending upon the kind of contacts which are to be used. One should remember that if brass bolts are used for contacts, the nuts and washers are larger than the bolt heads. One should space the holes so that the nut and washer of one contact will not touch those adjacent. Two holes should be drilled for the binding posts *Q* and *W*, Figure 1.

The movable base *L* is a square piece of dry wood 4 inches long, 4 inches wide, and about three-fourths inch thick. Care should be taken to have the ends of this block cut square with respect to the sides.

**FIXED COIL TUBE AND PANEL (*P* AND *K*, FIG. 1).**—The coil tube *P* (Fig. 1) is essentially the same as the tuner described in Circular No. 120, and the tuner used there may be made a part of *P* of this set. The cardboard cover should be glued to the end of the tube where the single turn taps are taken off. This tube (an oatmeal box) is about  $4\frac{1}{8}$  inches in diameter and 4 inches long. If a new coil tube is constructed, it may be improved by using a somewhat different arrangement of the twisted taps. (See coil marked "tuning coil" in Fig. 3, Circular No. 120.) Instead of taking off taps in a line from the upper right corner to

the lower left corner of the figure, start at the upper left corner and progress downward to the lower right corner. The end of the coil tube where the 10-turn taps are taken off should have the cardboard cover glued to it. This is the top of the coil tube as it is shown in the diagram (Fig. 3, Circular No. 120). In all other respects the tube is wound exactly as described in Circular No. 120.

The panel which was described in Circular No. 120 may also be used for the panel *K* (Fig. 1). If the receiving set described in Circular No. 120 has not been constructed, this panel may be made from a board  $7\frac{1}{2}$  inches long by  $4\frac{1}{2}$  inches wide and about one-half inch thick. The position of the contacts can best be determined by inserting the switch arms in their respective holes and turning the knobs so that the ends of the switch arms will describe arcs, as previously explained. The contacts, switch arms, and knobs are described in Circular No. 120.

**FIXED BASE AND COIL TUBE SUPPORT (*B* AND *J*, FIG. 1).**—The fixed base *B* is a piece of dry wood  $5\frac{1}{2}$  inches wide, 11 inches long, and about three-fourths of an inch thick. The support *J* for the fixed coil tube is  $5\frac{1}{2}$  inches wide (the width of the base), 6 inches long, and about one-half inch thick. Two screw holes are drilled in *J*, so that *J* may be screwed to the left-hand end of the fixed base *B*.

A strip of wood *I*, 11 inches long, five-sixteenths of an inch wide, and about one-fourth inch thick, is now fastened to the base by cigar-box nails or small brads so that it is even with the rear edge, as shown in the drawing (Fig. 1). The next step is to locate the strip *H* in such a position that the block *L* will slide easily back and forth the entire length of the fixed base *B*. Having found this position this strip is secured in the same manner as the strip *I*. Two thin wood cleats (one shown at *AA*, Fig. 1) are fastened under the ends of the fixed base *B*. It is, of course, understood that neither the movable coil tube *S* nor the switch contacts and binding posts have, up to the present time, been mounted on the upright panel *M*. The wooden parts for the loose coupler are now finished. Instructions are given below for treating with paraffin and assembling the parts.

#### 4. VARIABLE CONDENSER, CRYSTAL DETECTOR AND BASE

**VARIABLE CONDENSER (*C*, FIGS. 1 AND 2).**—The variable air condenser should have a maximum capacity of between 0.0004 and 0.0005 microfarads (400 to 500 micromicrofarads). The type pictured in Figure 1 is inclosed in a round metal case, but the

"unmounted" type may also be used. A person adept with the use of tools can make the variable air condenser, but a discussion of the method is not within the scope of this Circular. The baseboard *R* (Fig. 1) is about 10 inches long,  $5\frac{1}{2}$  inches wide, and three-fourths inch thick. This board is similar to the baseboard used for the set described in Circular No. 120. The strips of wood (See *AA*, Fig. 1) are fastened under the ends so that wires may be run underneath for connections. These strips should be the same thickness as those shown under the fixed base *B*. Drill the holes for the crystal detector binding post, the telephone receiver binding posts *U*, the hole *CC* for the wire from the clip, and two small holes (one hole shown at *BB*) for the wires from the condenser binding posts *Y* and *Y'*.

**CRYSTAL DETECTOR (*D*, FIGS. 1 AND 2).**—The galena crystal may be mounted as described in Circular No. 120, or it may be mounted as pictured in Figures 1 and 2. The holder for the crystal is a metallic pinch clip such as the ordinary battery test clip. This clip should be bent into a convenient shape so that it may be fastened to the base.

The wire *X*, which makes contact with the crystal, is a piece of fine wire (about No. 30) which is wound into the form of a spring and twisted around or soldered to a piece of copper wire (No. 24, same as used on coil tube *S*). The other end of the No. 24 bare copper wire is twisted tightly around a nail which passes through the binding post and has a wood knob or cork fixed to its end, as shown in Figure 2. It is desirable to have the fine wire (No. 30) of springy material such as German silver, but copper wire may be used if more convenient.

The importance of securing a tested galena crystal can not be emphasized too strongly, and it should be understood that results can not be obtained by using an insensitive crystal.

## 5. INSTRUCTIONS FOR ASSEMBLING AND WIRING

**PARAFFIN COATING.**—Thus far no instructions have been given to assemble the various parts. Before fastening the uprights to the bases and the coil tubes to the uprights, or attaching the metal parts, the wood parts and the coil tubes should be treated with paraffin. Provide a pan large enough for the base *B* ( $5\frac{1}{2}$  by 11 inches) and enough paraffin which, when melted, will just cover the piece of wood. A pan of this size will accommodate any of the other pieces. Keep the paraffin in the liquid state and dip the several wood pieces into the paraffin, one at a time. The

longer one leaves the wood in the liquid paraffin the better, but 5 to 15 minutes will do. If it is not at all convenient to dip the parts in paraffin, the paraffin may be applied while hot with a brush. The parts to be treated with paraffin are *J*, *K*, *L*, *M*, *P*, *S*, and *R*. Do not put paraffin on any metal part except when treating the wire on coil tubes *P* and *S*. Care should be taken in melting the paraffin so that it will not overheat and become ignited. Do not get it so hot that it smokes.

**COUPLER.**—The movable portion of the coupler should be assembled first. As shown in Figure 1, the fittings making up this part of the set are the movable base *L*, the coil-tube support *M* and the coil tube *S*. Screw the coil-tube support *M* to one end of the movable base *L*, using the holes previously drilled in *M*. See that *L* and *M* slide freely between the strips *H* and *I*. Insert in *M* the six switch contacts (brass bolts), the switch arm, and the binding posts (*Q* and *W*) in the proper holes which have been drilled. Adjust the switch arm until it presses firmly on the contact points (boltheads) and fasten the bare end of a No. 24 copper wire between the nuts on the end of the switch-arm bolt *Z* (Figs. 1 and 2) which projects through the panel *M*. Wind this wire into the form of a spiral of two or three turns like a clock spring and later connect the other end of this wire between the head and washer at the rear of the binding post *W*, as described in the paragraph below. Insert two small screws *V* (Fig. 1) in the panel *M*, so that the switch arms will not drop off the row of contact points when the knob is turned too far.

The coil tube *S* is now ready to be fastened in position on the panel *M*. Cut a 1-inch hole in the cardboard end of the coil tube and place it with the closed end next to the panel *M* in such a position that it will be just below the row of nuts and washers (switch contacts) and in the center of the panel *M* with respect to the sides. Fasten it to the panel with short wood screws. The switch-arm bolt with the spiral wire connected to it should project through the hole cut in the end of the coil tube. Thread the end of the wire from *Z* through a hole punched near the end of the coil tube next to the panel and connect this wire to the back of the binding post *W* (Figs. 1 and 2). The wire *F* (Fig. 2) is now connected to the back of the binding post *Q*. There now remain five twisted taps and one single wire to be connected to the six switch contacts. The taps should be cut off about  $1\frac{1}{2}$  inches from the coil tube and the insulation removed from the pairs of wires thus formed. Each pair of wires should be twisted

together, as shown at *J*, Figure 2. The connections are now made by clamping the five taps and also the end of the single wire between the nuts and washers on the contact bolts. The connections are clearly shown in the diagram.

We are now ready to assemble and wire the fixed portion of the coupler, composed of the base *B*, coil-tube support *J*, panel *K*, and coil tube *P*. As previously mentioned, the panel *K* is practically the same as the panel shown in Circular No. 120, except that for this purpose the original panel is mounted so that the edge which was originally at the bottom now becomes the left-hand edge. This brings the series of 10 contacts at the top of the panel in our present set. When the panel is turned to this position the two binding posts will be at the top. Change the position of the right-hand binding post so that the two are arranged as shown in Figure 1. Connections between the binding posts and switch arms are made as described in Circular No. 120. Two short pieces of stiff wire should now be fastened under the binding posts at the front of the panel to form a spark gap. These wires are arranged so that there is a very short space between their ends, as explained in Circular No. 120. Screw the panel *K* to the base *B* and to the support *J*, meanwhile allowing the coil tube *P* to lie on the base so that the connecting wires will not be broken.

If the panel *K* is to be made specially for the coupler, as described in this Circular, it should be mounted according to the following instructions:

Screw the panel to the base and to the support *J* and insert the binding posts, switch arms and bolts, and contact bolts in the proper holes. The switch arms should now be adjusted so that they make firm contact on the heads of the bolts. Now insert four small screws (*E*, Fig. 1) in the front of the panel so that the switch arms will not drop off the row of contact points when the knobs are turned too far. Insert a wire between the nuts on the end of the lower switch-arm bolt *N* where it projects through the back of the panel *K* (Fig. 1). Wind the wire into a spiral of one or two turns like a clock spring and connect the end to the upper binding post which is marked "antenna." These connections will be understood by referring to the upper left-hand corner of Figure 2.

In the same manner connect another wire from the upper switch-arm bolt to the lower binding post which is marked

"ground." (See Fig. 2.) The connecting wires should be insulated except where a connection is needed and should not touch each other. Two short pieces of wire are now fastened to the binding posts in the front of the panel, as previously explained.

The coil tube *P* should now be laid on the base in about the same position as is shown in Figure 1. The 16 twisted taps and also the 2 single wires from the ends of the winding are now to be connected to the back of the 18 contacts on the panel *K*, following the method given in Circular No. 120. The order of connecting the taps may be understood by referring to Figure 2.

The following instructions will apply whether the coil tube *P* was made according to the description in Circular No. 120 or was made according to instructions given in this circular:

Carefully raise the coil tube *P* against the support *J* to such a position that when the coil tube *S* of the movable section of the tuner is pushed in the coil tube *P* the space between the two tubes will be equal all around. Mark this position of the coil tube *P* on *J*, and fasten *P* to *J* with short wood screws.

CONDENSER AND CRYSTAL DETECTOR (*C* AND *D*, FIG. 1).—The mounting of the condenser *C* and the crystal detector *D* on the base *R* is clearly shown in Figure 1. Crystal detectors have been previously described in this circular and in Circular No. 120. A wire is run from the binding post *Y* on the variable condenser *C* through a small hole in the base *R*, and is then connected to the under side of the crystal detector binding post. Another wire is now run from the clip which holds the galena crystal through a small hole *CC* in the base, and is then connected to the under side of the right-hand binding post *U*. The left-hand binding post *U* is next connected to the binding post *Y'* of the variable condenser *C* by running a wire under the base and up through a small hole *BB*. The wiring will be understood by referring to the right-hand portion of Figure 2. The wires may be the same size as were used for winding the coil tubes and should be insulated. Two pieces of wire should now be connected from the binding posts *W* and *Q* (Figs. 1 and 2) to binding posts *Y* and *Y'* of the variable condenser *C*. The telephone receivers *T* are now connected to the binding posts *U* and the receiving set is complete except for connecting to the antenna and ground.

The connection of the antenna lead and ground wire to the binding posts marked "antenna" and "ground," respectively, is made as shown in Figure 2 in Circular No. 120.

## 6. DIRECTIONS FOR OPERATING

Push the coil tube *S* (secondary) about halfway into the coil tube *P* (primary) and set the switch *Z* on contact point 4. The primary switch *N* is set on contact point 8. The primary switch *O* may be left in any position.

The crystal detector can be adjusted most easily by the use of the test buzzer, which is described below. If the test buzzer is not used, the wire which rests on the crystal must be placed lightly at different points on the crystal until the transmitting station is heard, when the set is adjusted as described below. To adjust the crystal by either method, first push the coil tube *S* (secondary) about halfway into the coil tube *P* (primary), set the secondary switch arm *Z* on contact point 4, the primary switch arm *N* on contact point 8, while the primary switch arm *O* and the pointer of the variable condenser (*C*) may be left in any position.

Having adjusted the crystal detector to a sensitive point as described below, the next thing is to adjust the switches (*N* and *O*) on the coil tube *P* (primary), the switch (*Z*) on the coil tube *S* (secondary), and also the variable condenser *C*, so that the apparatus will be in "resonance" with the transmitting station. Again insert the secondary coil tube *S* about halfway into the coil tube *P* and set the secondary switch arm on contact point 4 and the pointer of the condenser in any position. Set the primary switch *N* on contact point 1, and while keeping it in this position move the other primary switch *O* over all of its contacts, stopping a moment at each one, being sure that the ends of the switch arms rest on only one contact point at a time. If no signals are heard, set the switch arm *N* on contact point 2 and again move the switch arm *O* over all of its contacts. Proceed in this manner until the transmitting station is heard. This is called "tuning" the primary circuit.

The tuning of the secondary circuit is the next operation. Set the secondary switch arm *Z* on contact point 1 and turn the knob of the variable condenser *C* so that the pointer moves over the entire scale. If no signals are heard, set the switch arm *Z* on contact point 2 and again turn the knob of the variable condenser so that the pointer moves over the entire scale. Proceed in this manner over all the contact points until the signals are loudest. Next slide the coil tube *S* (secondary) in and out of the coil tube *P* (primary) until the signals are made as loud as possible. This

operation is called changing the "coupling." When the coupling which gives the loudest signal has been secured, it may be necessary to slightly readjust the position of the switch arm *O*, the position of the movable coil tube *S*, and the "setting" of the variable condenser *C*.

The receiving set is now in resonance with the transmitting station. It is possible to change the position of one or more of the switch arms, the position of the movable coil tube, and the setting of the variable condenser in such a manner that the set will still be in resonance with the same transmitting station. In other words, there are different combinations of adjustments which will tune the set so that it will respond to signals from the same transmitting station. The best adjustment is that which reduces the signals from undesired stations to a minimum and still permits the desired transmitting station to be heard. This is accomplished by decreasing the coupling (drawing coil tube *S* farther out of coil tube *P*) and again tuning with the switch arm *O* and the variable condenser *C*. This may also weaken the signals from the desired transmitting station, but it will weaken the signals from the undesired stations to a greater extent, provided that the transmitting station which it is desired to hear has a wave frequency (wave length) which is not exactly the same as that of the other stations. This feature is called "selectivity."

**THE TEST BUZZER.**—As mentioned above, it is easy to find the more sensitive spots on the crystal by using a test buzzer. This has been described in Circular No. 120 and is shown at *Z*, Figure 3, in that publication. Referring to this figure, the binding post marked "ground" should be connected by a flexible wire to the binding post *W*, which is shown in Figure 1 in this circular. The operation of the test buzzer has been described in Circular No. 120.

## 7. APPROXIMATE COST OF PARTS

The following parts are used in the equipment described in Circular No. 120 and are needed also for the two-circuit set described in this circular. Some of the prices have been revised.

### Antenna:

Wire, copper, bare or insulated, No. 14 or 16, per 100 feet about.....	\$0.90
Rope, one-fourth or three-eighths inch, 2 cents per foot.....	
2 insulators, porcelain cleats.....	.20
1 pulley.....	.15
Lightning switch, 30-ampere battery switch.....	.50
1 porcelain tube.....	.10

**Ground connections:**

Wire (6 feet No. 10 or heavier copper wire).....	\$0.15
2 clamps.....	.30
1 iron pipe or rod.....	.25

**Receiving set:**

3 ounces No. 24 double cotton-covered copper wire.....	.40
1 round cardboard box.....	
2 switch knobs and blades, complete.....	1.00
18 switch contacts and nuts.....	.75
3 binding posts, set-screw type.....	.45
2 binding posts, any type.....	.30
1 crystal, tested.....	.25
3 wood screws, brass, three-fourths inch long.....	.03
2 wood screws for fastening panel to base.....	.02
Wood for panels (from packing box).....	
2 pounds paraffin.....	.30
Lamp cord, 4 cents per foot, about.....	.40
Test buzzer.....	.75
Dry battery.....	.40
Telephone receivers <sup>1</sup> .....	4.00 to 8.00

Total, about..... 11.60 to 15.60

**The following additional parts will be required:**

3 ounces No. 24 double cotton-covered copper wire.....	.40
1 round cardboard box.....	
1 switch knob and blade, complete.....	.50
6 switch contacts and nuts.....	.25
2 binding posts, any type.....	.30
1 battery clip for crystal.....	.10
Miscellaneous screws.....	.15
1 variable condenser, 0.0004 to 0.0005 microfarads (400 to 500 micro- microfarads).....	1.50 to 6.00

Total additional cost, about..... 3.20 to 7.70

<sup>1</sup> Still more efficient and expensive telephone receivers may be obtained at prices up to about \$20.

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DEPARTMENT OF COMMERCE

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# CIRCULAR

OF THE

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S. W. STRATTON, DIRECTOR

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No. 122

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## SOURCES OF ELEMENTARY RADIO INFORMATION

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JUNE 22, 1922



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## SOURCES OF ELEMENTARY RADIO INFORMATION

### ABSTRACT

The developments in radio communication have been so rapid that much important radio information has not yet been collected in books, but must be sought in periodicals and other sources. A number of important books have appeared recently and are not generally known. The Bureau of Standards is constantly receiving requests for radio information. Many of the inquiries call for the same information, and in order to facilitate the handling of such inquiries this Circular has been prepared. This Circular gives information concerning radio periodicals, radio books issued by various publishers, Government radio publications issued by various bureaus, including the publications of the Bureau of Standards, radio laws and regulations, and call letters, and answers a few of the most usual elementary questions concerning radio communication which are asked by the novice.

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### 1. INTRODUCTION

A very considerable number of persons are interested in the operation of radio stations who are not directly concerned with the operation of either Government or regular commercial radio stations. Some are interested in maintaining a private system of radio communication over comparatively short distances. Many are interested in radio because it offers a very fascinating experimental field. Different kinds of useful information, such as weather reports, market reports, time signals, and music and

other entertainment, are transmitted broadcast daily by radio, and are received by many persons in all parts of the United States. This radio broadcasting has recently grown very rapidly and has become very popular, and has resulted in the installation of receiving sets by persons who previously had never had any interest in radio.

## 2. PERIODICALS

Persons interested in radio communication along the lines mentioned above can keep in touch with radio developments which will be of value to them by arranging to see regularly the issues of one or more of the following periodicals (monthly except as stated) which cover the general and elementary phases of radio communication:

- QST—Published by the American Radio Relay League, Hartford, Conn.
- Radio news, 235 Fulton Street, New York, N. Y.
- Wireless age, 326 Broadway, New York, N. Y.
- Radio telegrapher, 44 Broad Street, New York, N. Y.
- Radio (formerly Pacific radio news), 151 Minna Street, San Francisco, Calif.
- Radio topics, 1112 North Boulevard, Oak Park, Ill.
- Telegraph and telephone age (semimonthly), 253 Broadway, New York, N. Y.
- Radio (formerly Aviation and wireless news), 60 East Adelaide Street, Toronto, Ontario.
- Wireless world and radio review (weekly), 12 Henrietta Street, London, England.

To meet a widespread popular demand for radio information there have recently been started a number of new periodicals of a popular nature devoted wholly or in part to radio. Since these periodicals are so new, it is difficult to give definite information as to the field covered by each. Below are listed a number of these newer periodicals to which attention has been called. (It is realized that this list is probably incomplete.)

- Radio broadcast, Doubleday, Page & Co., Garden City, N. Y.
- Popular radio, 9 East Fortieth Street, New York, N. Y.
- Radio world, 1493 Broadway, New York, N. Y.
- Radio digest, 800 North Clark Street, Chicago, Ill.
- National radio review, 705 McGee Street, Kansas City, Mo.
- Radio dealer, 1133 Broadway, New York, N. Y.
- Radio merchandising, 342 Madison Avenue, New York, N. Y.
- Radio Life, 29 Temperance Street, Toronto, Ontario.
- Radio Journal, 113 Stimson Building, Los Angeles, Calif.
- American Radio Journal, 116 West Thirty-ninth Street, New York, N. Y.

The New York Globe and the New York Evening Mail each Saturday issue radio magazine supplements which contain articles of popular radio interest.

The United States Department of Commerce, Bureau of Navigation, issues a monthly periodical called the Radio Service

Bulletin, which will be found of considerable interest by every person engaged in radio communication. This periodical contains information regarding changes in the radio regulations, traffic information, and lists additions to, or changes in the list of Commercial and Government Radio Stations, and brief items regarding new developments in radio. Publications of radio interest issued by various Government departments, including the Bureau of Standards, are announced as soon as issued. Subscriptions for the Radio Service Bulletin may be placed with the Superintendent of Documents, Government Printing Office, Washington, D. C. The subscription price is 25 cents per year for subscribers in the United States and its possessions, Canada, Cuba, and Mexico. For other countries the subscription price is 40 cents per year.

Most of the general electrical periodicals, and the popular scientific periodicals, now devote considerable space to radio.

Persons who have had technical training in electricity and radio communication will be interested in the Proceedings of the Institute of Radio Engineers, One hundred and fortieth Street and Convent Avenue, New York, N. Y. Articles of radio interest frequently appear also in the Journal of the American Institute of Electrical Engineers, 29 West Thirty-ninth Street, New York, N. Y.

### 3. GOVERNMENT RADIO PUBLICATIONS

The Superintendent of Documents, Government Printing Office, Washington, D. C., will send without charge, on request, a copy of his Price List No. 64, which lists Government publications of radio interest.

A considerable number of papers on radio subjects have been issued by the radio laboratory of the Bureau of Standards. Some of these have been published by the Government Printing Office and some of these have been published in various periodicals. Most of these papers are primarily of interest to the radio engineer and scientist. Bureau of Standards Letter Circular No. 40, Radio Publications of the Bureau of Standards, which lists these publications, may be secured by addressing a request to the Bureau of Standards, Washington, D. C. The bureau's publications issued by the Government Printing Office which are of most general radio interest are listed below. The Bureau of Standards can not undertake to send individual notices of its new radio publications as they are issued. Prompt notices of such publications appear in the Radio Service Bulletin and in other periodicals, including those mentioned above, and state the price at which

such publications may be purchased from the Superintendent of Documents.

The Principles Underlying Radio Communication, Signal Corps Radio Communication Pamphlet No. 40, is an elementary book prepared by the Bureau of Standards. It contains over 600 pages and more than 300 illustrations, and is durably bound in fabrikoid. It was prepared primarily as a textbook for use in the instruction of Signal Corps men, but has also been used in schools and colleges. It is assumed that the reader has had at least the major part of a high-school course, but no knowledge of mathematics beyond algebra is assumed. The first 200 pages are devoted to an introductory general discussion of electricity and electrical machinery, and the rest of the book to the fundamental principles of radio communication. The construction and operation of the important types of radio transmitting and receiving apparatus are discussed. There are numerous circuit diagrams and useful tables. The operation of electron tube transmitting and receiving sets, including radio telephone sets, is discussed. A copy of the 1922 edition of this book can be purchased for \$1 from the Superintendent of Documents. This price includes postage in the United States and its possessions, Canada, Cuba, and Mexico. For other countries, 15 cents additional for postage.

Radio Instruments and Measurements, Bureau of Standards Circular No. 74, will be found of interest by any one who is interested in technical radio theory or who wishes to make radio measurements of any kind. It is a book of 341 pages and covers thoroughly a wide variety of radio measurements. A copy may be purchased for 60 cents from the Superintendent of Documents. Foreign postage, 15 cents extra.

Construction and Operation of a Simple Home-Made Radio Receiving Outfit, Bureau of Standards Circular No. 120, describes a very simple single-circuit crystal detector set which can be made in the home. Price 5 cents.

Construction and Operation of a Two-Circuit Radio Receiving Equipment with Crystal Detector, Bureau of Standards Circular No. 121, describes another type of receiving set which can be made in the home, which is not quite as simple and will give more selective reception than the set described in Circular No. 120. Price, 5 cents.

Three letter circulars of the Bureau of Standards are available only in mimeographed form. A copy of any of these may be secured by any person having actual use for it on application to the bureau so long as a supply is available.

B. S. Letter Circular No. 41, Extension of the Dewey decimal classification applied to radio. December 17, 1920.

B. S. Letter Circular No. 56, Methods of radio direction finding as an aid to navigation: The relative advantages of locating the direction finder on shore and on ship-board. March 27, 1922.

B. S. Letter Circular No. 62, Proposed revision of rule 86 of the "National electrical code," on radio equipment, with discussion and explanation prepared by the radio section of the Bureau of Standards. May 1, 1922.

B. S. Letter Circular No. 66. List of manufacturers and sole United States distributors of radio receiving equipment. June 1, 1922.

Papers by members of the staff of the bureau describing radio work performed at the bureau have appeared in various periodicals from time to time, including: Proceedings of the Institute of Radio Engineers, Journal of the American Institute of Electrical Engineers, QST, Wireless Age, Physical Review, Journal Washington Academy Sciences, Radio News, and Scientific American. These papers are listed in Bureau of Standards Letter Circular No. 40, which is mentioned above. Copies of these papers published in outside periodicals can not be furnished by the bureau, but must be consulted in the periodicals in which they are printed.

The following Scientific Papers of the Bureau of Standards are of radio interest, and may be purchased from the Superintendent of Documents, at the prices stated:

- S169. Formulas and tables for the calculation of mutual and self inductance; by Rosa and Grover. 3d ed. 1916. 20 cents. (See also S320.)
- S206. High frequency ammeters; by J. H. Dellinger. 1913. 10 cents.
- S234. Insulating properties of solid dielectrics; by H. L. Curtis. 1914. 15 cents.
- S235. A direct reading instrument for measuring the logarithmic decrement and wave length of electromagnetic waves; by F. A. Kolster. 1914. 10 cents.
- S269. Effect of imperfect dielectrics in the field of a radiotelegraphic antenna; by J. M. Miller. 1916. 5 cents.
- S320. Additions to the formulas for the calculation of mutual and self inductance; by F. W. Grover. 10 cents. (Supplementing S169.)
- S326. Electrical oscillations in antennas and inductance coils; by J. M. Miller. 1918. 5 cents.
- S341. Airplane antenna constants; by J. M. Cork. 1919. 5 cents.
- S351. Dependence of the input impedance of a three-electrode vacuum tube upon the load in the plate circuit; by J. M. Miller. 1919. 5 cents.
- S353. Variation in direction of propagation of long electromagnetic waves; by A. H. Taylor. 1919. 5 cents.
- S354. Principles of radio transmission and reception with antenna and coil aerials; by J. H. Dellinger. 1919. 10 cents.
- S355. Determination of the output characteristics of electron tube generators; by L. M. Hull. 1919. 5 cents.
- S381. An electron tube transmitter of completely modulated waves; by L. M. Hull. 1920. 5 cents.
- S423. Operation of the modulator tube in radio telephone sets; by E. S. Purington. 1921. 10 cents.
- S427. Some effects of the distributed capacity between inductance coils and the ground; by G. Breit. 1921. 5 cents.

S428. The radio direction finder and its application to navigation; by F. A. Kolster and F. W. Dunmore. 1922. 15 cents.

S430. The high-frequency resistance of inductance coils; by G. Breit. 1922. 5 cents.

S431. The field radiated from two horizontal coils; by G. Breit. 1922. 5 cents.

The following two Signal Corps publications are useful to the beginner and may be purchased from the Superintendent of Documents at the price stated:

Elementary principles of radio telephony. Signal Corps Radio Communication Pamphlet No. 1. 1921. 79 p. 10 cents.

Elementary electricity. Signal Corps Training Pamphlet No. 1. 1921. 52 p. 15 cents.

#### 4. BOOKS

In the past few years a considerable number of books have been published to meet the needs of the various classes of readers interested in radio. Below are listed some of the more important books which are particularly likely to be of interest to the elementary student. No effort has been made to list all of the radio books published. The division into classes according to difficulty is more or less arbitrary, and is simply intended as a general guide to help the person who has no familiarity with the literature.

Very recently there have appeared a considerable number of inexpensive books and pamphlets of a very elementary nature issued by various publishers, which offer explanations of radio phenomena and give instructions for construction and operation of radio sets. The accuracy and value of these publications varies widely, and no attempt has been made to list them here.

##### (a) BOOKS SUITABLE FOR THE BEGINNER

E. E. Bucher. Practical wireless telegraphy. New York, 1918. Wireless Press (Inc.).

E. E. Bucher. Wireless experimenters manual. New York, 1920. Wireless Press (Inc.).

Charles B. Hayward. How to become a wireless operator. Chicago, 1918. American Technical Society.

Robison's manual of radio telegraphy and telephony. Annapolis, Md., 1920. United States Naval Institute.

The Admiralty manual of wireless telegraphy. London, 1920. Published by His Majesty's Stationery Office.

M. B. Sleeper. Design data for radio transmitters and receivers. New York, 1920. Norman W. Henley Publishing Co.

M. B. Sleeper. Construction of radio phone and telegraph receivers for beginners. New York, 1922. Norman W. Henley Publishing Co.

M. B. Sleeper. How to make commercial type radio apparatus. New York, 1922. Norman W. Henley Publishing Co.

P. E. Edelman. Experimental wireless stations. New York, 1920. Norman W. Henley Publishing Co.

A. C. Lescarbours. Radio for everybody. New York, 1922. Scientific American Publishing Co.

- Morecroft, Hazeltine, Goldsmith, Pupin, and others. Radiophone receiving. New York, 1922. D. Van Nostrand Co.
- Dellinger and Whittemore. Radio handbook. Philadelphia, Pa., 1922. Lefax (Inc.). The easy course in home radio. New York, 1922. Review of Reviews Co.
- Yates and Pacent. The complete radio book. New York, 1922. Century Co.
- W. C. Ballard. Elements of radio telephony. New York, 1922. McGraw-Hill Book Co.
- Snodgrass and Camp. Radio receiving for beginners. New York, 1922. The Macmillan Co.

(b) **ELEMENTARY TEXTS FOR STUDY**

- The principles underlying radio communication. Signal Corps Radio Communication Pamphlet No. 40. Revised Edition. Washington, 1922. Government Printing Office. Price \$1. (See more extended notice on page 3.)
- G. D. Robinson. Modern theory and practice in radio communication. Annapolis, Md., 1920. United States Naval Institute.
- E. W. Stone. Elements of radio telegraphy. New York, 1919. D. Van Nostrand Co.
- J. C. Hawkhead and H. M. Dowsett. Handbook of technical instruction for wireless telegraphists. London, 1918. Wireless Press (Ltd.).
- A. N. Goldsmith. Radio telephony. New York, 1918. Wireless Press (Inc.).
- R. D. Bangay. The oscillation valve. London, 1919. Wireless Press (Ltd.).
- Lauer and Brown. Radio engineering principles. New York, 1920. McGraw-Hill Book Co.
- John Scott-Taggart. Elementary text-book on wireless vacuum tubes. London, 1922. Radio Press, (Ltd.).

(c) **MORE ADVANCED TEXTS SUITABLE FOR REFERENCE**

- Bureau of Standards Circular No. 74. Radio instruments and measurements. Washington, 1918. Government Printing Office. 60 cents. (See more extended notice on page 4.)
- H. M. Dowsett. Wireless telegraphy and telephony. London, 1920. Wireless Press (Ltd.).
- Rupert Stanley. Textbook of wireless telegraphy. (2 vols.) London, 1919. Longmans Green & Co.
- J. H. Morecroft. Principles of radio communication. New York, 1921. John Wiley & Sons.
- J. A. Fleming. The principles of electric wave telegraphy. (4th Ed.) London, 1919. Longmans Green & Co.
- J. A. Fleming. The wireless telegraphist's pocket book of notes, formulae, and calculations. London, 1915. Wireless Press (Ltd.).
- W. H. Eccles. Wireless telegraphy and telephony. London, 1918. Benn Bros. (Ltd.).
- John Scott-Taggart. Thermionic tubes in radio telegraphy. London, 1921. Wireless Press (Ltd.).
- B. Leggett. Wireless telegraphy, with special reference to the quenched spark system. London, 1921. Chapman & Hall (Ltd.).
- L. B. Turner. Wireless telegraphy and telephony. Cambridge, England, 1921. Cambridge University Press.

(d) **YEAR BOOK**

A valuable reference book on matters of radio interest is the Year Book of Wireless Telegraphy, published in May of each year by the Wireless Press (Ltd.),\* 12 Henrietta Street, London, England.

## 5. CODES

In radio telegraphy, signals are transmitted by dots and dashes arranged according to the International Morse Code, sometimes called the Continental Code. The International Morse Code is different from the American Morse Code, which is used on land lines in the United States. The International Morse Code is given in the *Principles Underlying Radio Communication*, in the books by Robinson, Robison, and Hayward, mentioned above, and also in the pamphlet, *Radio Communication Laws of the United States*, mentioned below. The International Morse Code is also given on a small card (Form 773a) published by the Bureau of Navigation. A copy of this card may be procured without charge on application to the Bureau of Navigation, Department of Commerce, Washington, D. C., or to any of the district radio inspectors whose addresses are given below.

## 6. DIFFICULTIES IN TRANSMISSION

Persons contemplating the installation of radio stations which are expected to maintain reliable radio communication at all times, particularly radio telephony, are reminded that radio communication is often subject to serious interference from atmospheric electric disturbances, which are particularly serious in the summer. Other difficulties in transmission may also exist. Information regarding the actual operating conditions in a given locality should be obtained whenever possible from the operators of radio stations in the locality in question.

## 7. SAFETY PRECAUTIONS

The ordinary precautions required for the safe operation of any electrical equipment should be observed in every radio station. All high-voltage wiring should be carefully insulated and kept as far as possible from other wiring and so placed as to minimize the possibility that the operator may come in contact with it, and suitable danger tags should be displayed.

Insurance companies make certain requirements regarding electrical installations in any buildings on which they carry risks. Information regarding such requirements may be secured from the National Board of Fire Underwriters, 76 William Street, New York, N. Y., or from local insurance inspection offices. These requirements are summarized in a small book, the *National Electrical Code*, which contains a section covering special requirements for radio installations. A copy of this book may be secured for 10 cents from the National Board of Fire Underwriters. A brief

discussion of safety precautions in radio installations may be found in the book, the *Principles Underlying Radio Communication*, mentioned above.

At the time of the publication of this Circular consideration is being given to a proposed revision of Rule 86 of the National Electrical Code, covering radio equipment. The proposed revision is given in Bureau of Standards Letter Circular 62, Proposed Revision of Rule 86 of the "National Electrical Code" on Electrical Equipment, with Discussion and Explanation Prepared by the Radio Laboratory of the Bureau of Standards. A very limited supply of Letter Circular 62 is available for distribution to persons having actual use for it, and so long as the supply is available a copy will be sent on application to the Bureau of Standards.

#### 8. RECEPTION IN RADIO TELEPHONY

The apparatus ordinarily required for reception in radio telephony is the same as that ordinarily used for reception in radio telegraphy. The transmitting apparatus, however, differs essentially.

#### 9. RADIO LAWS AND REGULATIONS

Every person engaged in the handling of radio traffic should be thoroughly familiar with the radio communication laws of the United States and the International Radiotelegraphic Convention. These are printed in a pamphlet, *Radio communication laws of the United States*, of which copies may be purchased for 15 cents each from the Superintendent of Documents, Government Printing Office, Washington, D. C.

The law provides that in order to operate a radio transmitting station, both a *station* license and an *operator* license must be secured. The law provides penalties for the operation of a transmitting station without proper licenses.

A station used only for receiving does not require a station license. Operators of stations used only for receiving do not require operators' licenses, but must maintain secrecy in regard to messages heard.

Provision is now made for eight classes of land stations:

- (1) Public service stations, general.
- (2) Public service stations, limited.
- (3) Limited commercial stations.
- (4) Experiment stations.
- (5) Technical and training-school stations.
- (6) Special amateur stations.
- (7) General amateur stations.
- (8) Restricted amateur stations.

Station licenses for Classes 4, 5, and 6 are issued only under exceptional circumstances, as set forth in the pamphlet mentioned above.

General amateur stations are restricted to a transmitting wave length not exceeding 200 meters and a transformer input not exceeding 1 kilowatt.

Restricted amateur stations are amateur stations located within five nautical miles of a naval or military station and are restricted to a wave length not exceeding 200 meters and to a transformer input not exceeding one-half kilowatt.

If a transmitting station radiates more than one wave length, the energy in no one of the lesser waves shall exceed 10 per cent of the energy in the principal wave.

The logarithmic decrement per complete oscillation must not exceed two-tenths.

Amateur station licenses contain the following clause: "This station is not licensed to broadcast weather reports, market reports, music, concerts, speeches, news, or similar information or entertainment."

Operators' licenses are divided into the following classes: Commercial extra first grade, commercial first grade, commercial second grade, commercial cargo grade, commercial temporary permit, experiment and instruction grade, amateur first grade, and amateur second grade. In order to obtain an operator's license of any grade, it is necessary to pass an examination showing certain qualifications, as set forth in the pamphlet mentioned above. For the amateur licenses an operator must be sufficiently familiar with the International Morse Code to receive at a speed of at least ten words per minute.

Both station licenses and operators' licenses are issued by the Bureau of Navigation of the Department of Commerce, Washington, D. C. The United States is divided into nine radio districts. Each district has a radio inspector who has charge of the issuing of both station licenses and operators' licenses in his district. Application for either kind of license should be addressed to the radio inspector of the district in which the station is located, or, if this is not known, to the Bureau of Navigation, Department of Commerce, Washington, D. C.

The offices of the radio inspectors are located as follows:

First District, Radio Inspector, Customhouse, Boston, Mass.

Second District, Radio Inspector, Customhouse, New York, N. Y.

Third District, Radio Inspector, Customhouse, Baltimore, Md.

Fourth District, Radio Inspector, Customhouse, Baltimore, Md.

Fifth District, Radio Inspector, Customhouse, New Orleans, La.

Sixth District, Radio Inspector, Customhouse, San Francisco, Calif.

Seventh District, Radio Inspector, 2301 L. C. Smith Building, Seattle, Wash.

Eighth District, Radio Inspector, Federal Building, Detroit, Mich.

Ninth District, Radio Inspector, Federal Building, Chicago, Ill.

#### 10. CANADIAN RADIO LAWS

The laws regulating the operation of private radio stations in Canada are in several respects quite different from those in force in the United States. For instance, a station which is used only for receiving must have a station license, but is not restricted as to the length of its antenna. Every person operating any kind of a radio station in Canada, for either receiving or transmitting, must have a "certificate of proficiency," or operator's license. A "certificate of proficiency" can not be issued to a person who is not a British subject. Amateur experimental stations used for transmitting are restricted to wave lengths of 50, 100, 150, or 200 meters, according to their distance from commercial land stations or routes of navigation. Stations located within 5 miles of a commercial coast or land station, or a route of navigation, can not use a transmitting wave length greater than 50 meters. The Canadian laws and regulations are printed in the Year Book of Wireless Telegraphy. Changes in the Canadian regulations are now under consideration. For authoritative information inquiry should be made of the Deputy Minister of the Naval Service, Ottawa, Ontario, who will supply for 10 cents a pamphlet containing the Canadian laws and regulations.

#### 11. STATION CALL LETTERS

*Amateur Calls.*—The station license issued for the operation of an amateur transmitting station in the United States designates a call which is to be used by that station at all times.. This call consists usually of a number followed by two letters, as 1AB, but may consist of a number followed by three letters, as 1ABC. The number is the number of the radio district in which the station is located. Experiment stations have calls consisting of a number followed by two or three letters of which the first one is X, as 1XA. Technical and training-school stations have calls consisting of a number followed by two or three letters of which

the first one is Y, as 1YA. Special amateur stations have calls consisting of a number followed by two or three letters of which the first one is Z, as 1ZA. It is unlawful for any transmitting station at any time to sign any call except the call assigned in its station license. No station is allowed to transmit until a station license is issued. The radio regulations formerly provided that after an application for a station license had been filed and pending the issue of the station license, a provisional call could be used and the station could transmit; this provision has been repealed.

*Canadian Amateur Calls.*—Canadian amateur stations are assigned calls consisting of a number followed by two or three letters, like the calls assigned to amateur stations in the United States. The Canadian stations having calls beginning with the numbers 1, 2, and 3 are in the southeastern part of Canada, somewhat near to the United States stations having calls beginning with 1, 2, 3. Therefore it is possible for a Canadian station having a call, say 1AB, to work with a United States station having the same call 1AB. Operators who make a practice of working Canadian stations have devised various means for avoiding confusion. The Canadian Department of the Naval Service has under consideration the changing of Canadian calls to eliminate this difficulty.

## 12. LISTS OF RADIO CALLS

Every radio amateur should also have a copy of the pamphlets *Amateur Radio Stations of the United States*, and *Commercial and Government Radio Stations of the United States*. The price of each of these pamphlets is 15 cents, and orders should be sent to the Superintendent of Documents, Government Printing Office, Washington, D. C. These pamphlets contain lists of the amateur and commercial and Government transmitting stations in the United States and of the call letters assigned to the stations; a new edition of each pamphlet is published on June 30 of each year. The monthly publication called the *Radio Service Bulletin* mentioned above contains information regarding changes in the radio regulations; traffic information, and lists additions to or other changes in the list of Commercial and Government Radio Stations.

A Consolidated Radio Call Book is published by the Consolidated Radio Call Book Co., 41 Park Row, New York, N. Y. This gives the calls of both United States and foreign stations.

A list of commercial and Government stations operating in the United States and in foreign countries is given in the *Year Book of Wireless Telegraphy*, mentioned above.



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DEPARTMENT OF COMMERCE.

U.S. BUREAU OF STANDARDS.

S. W. STRATTON, Director

CIRCULAR OF THE BUREAU OF STANDARDS.

No. 123.

Issued July 27, 1922.

UNITED STATES GOVERNMENT SPECIFICATION FOR  
WHITE FLOATING SOAP.

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION No. 26.

This Specification was officially adopted by the Federal Specifications Board on June 20, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of materials covered by it.

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1. GENERAL.

The soap desired under this specification is a high-grade cake soap, at least as good in every respect as one made from soda and a mixture of high-grade tallow with 25 to 30 per cent of coconut oil, of good light color, thoroughly saponified, and so prepared as to float on water. Bidder shall state size, weight, and number of cakes in each box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 34 per cent. Deliveries which yield more than 34 per cent volatile matter will be rejected without further test.

The sum of free alkali, total matter insoluble in alcohol, and sodium chloride shall not exceed 2.0 per cent.

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Gift of U. S. Govt.

Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.15 per cent.

Chloride, calculated as sodium chloride (NaCl), shall not exceed 1 per cent.

Matter insoluble in water shall not exceed 0.2 per cent.

Rosin, sugar, and foreign matter shall not be present.

The acid number of the mixed fatty acids prepared from the soap must be not less than 212.

Odor and character of cake must be as specified by the purchaser.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constituents will be calculated on the basis of material containing 28 per cent of volatile matter.

The material will be purchased by net weight, provided the matter volatile at 105° C. does not exceed 28 per cent. With deliveries containing more than 28 per cent but not exceeding 34 per cent of matter volatile at 105° C. settlement will be made on the basis of 28 per cent of matter volatile at 105° C.; that is, seventy-two one-hundredths of a pound of nonvolatile matter shall be considered 1 pound of soap.

*Examples.*—1. Yield 27 per cent of matter volatile at 105° C., pay for net weight.

2. Yield 30 per cent of matter volatile at 105° C., percentage of net weight to be paid for is calculated as follows:

$$(100 - 30) \times \frac{100}{72} = 97.22 \text{ per cent.}$$

## 2. SAMPLING.

One cake shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 50 pounds each. In the case of smaller containers a cake shall be taken at random from each lot of containers totaling not to exceed 5,000 pounds. The total sample shall in all cases consist of not less than three cakes taken at random from separate containers. With very large lots, where the sample drawn as above will amount to more than 20 pounds the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds.

Wrap the individual cakes tightly in paraffined paper at once and seal by rubbing the edges with a heated iron. The inspector

should accurately weigh each wrapped cake, record its weight and the date of weighing on the wrapper, place the wrapped cakes in an air-tight container, which should be nearly filled, seal, mark, and send to the laboratory for test. Samples should be kept cool until tested. The seller shall have the option of being represented at the time of sampling and when he so requests shall be furnished with a duplicate sample.

### 3. LABORATORY EXAMINATION.

(a) **PREPARATION OF SAMPLE.**—In case of samples that can be easily disintegrated and mixed, run the entire sample through a suitable chopper, except where the sample is large, when each cake may be quartered and one-quarter of each cake run through the chopper. With samples that can not be handled as above, select a cake of average weight, quarter by cutting at right angles in the center, and shave equally from all freshly cut surfaces sufficient soap for analysis. Mix and weigh out all portions for analysis promptly. Preserve the remainder in an air-tight container in a cool place.

When a determination shows nonconformity with specification a duplicate shall be run.

(b) **MATTER VOLATILE AT 105° C.**—Weigh 5 g of the sample in a porcelain or glass dish about 6 to 7 cm in diameter and 4 cm deep, dry to constant weight in a vacuum oven or an inert atmosphere at a temperature not exceeding 105° C. (Note.—Time can be saved by having a layer of about 3 mm of ignited sand and a small stirring rod weighed with the dish, and dissolving the sample in absolute alcohol, evaporating to dryness, breaking up the sample with the rod, adding more alcohol, again evaporating and completing the drying in the oven as above.) Report loss in weight as matter volatile at 105° C.

(c) **TOTAL MATTER INSOLUBLE IN ALCOHOL, FREE ALKALI, OR FREE ACID.**—(1) *Matter Insoluble in Alcohol.*—Digest hot a 10 g sample with 200 cc of freshly boiled neutral ethylalcohol (94 per cent or higher). Filter through a counter-poised filter paper neutral to phenolphthalein, or a weighed Gooch crucible with suction, protecting the solution during the operation from carbon dioxide and other acid fumes. Wash the residue on the paper, or in the crucible, with hot neutral alcohol until free from soap. Dry the filter paper, or crucible, and residue at 100 to 105° C. for three hours, cool, and weigh the total matter insoluble in alcohol.

(2) *Free Alkali or Free Acid.*—Titrate the filtrate from the above, using phenolphthalein as indicator, with standard acid or

alkali solution, and calculate the alkalinity to sodium hydroxide (or potassium hydroxide) or acidity to oleic acid.

(3) *Matter Insoluble in Water*.—Proceed as in the determination of matter insoluble in alcohol. After filtering and thoroughly washing the residue, extract it with water at 60° C. and wash the filter thoroughly. (When the matter insoluble in water is all inorganic, boiling water may be used for the extraction and washing.) Dry the filter and residue at 100 to 105° C. for three hours, cool, and weigh matter insoluble in water. The nature of this may be determined by further examination.

(d) *CHLORIDE*.—Dissolve 5 g of the sample in 300 cc of water, boiling, if necessary, to effect solution of all soluble matter. Add an excess of neutral chlorine-free magnesium nitrate solution (about 25 cc of a 20 per cent  $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$  solution). Without cooling or filtering titrate with standard silver nitrate solution, using potassium chromate as indicator. Calculate the chloride as sodium chloride.

(e) *ACID NUMBER*.—(1) *Preparation of Fatty Acids*.—Dissolve about 50 g of the soap in 300 cc of hot water, transfer to a separatory funnel, add 150 cc of approximately 2N  $\text{H}_2\text{SO}_4$ , cool somewhat, add 120 cc of ether, shake, draw off the acid layer, and wash the ether layer free from acid with a strong salt ( $\text{NaCl}$ ) solution. Then draw off the aqueous layer as completely as possible, transfer the ether layer to a flask (it is not necessary to transfer quantitatively), add 20 to 30 g of anhydrous sodium sulphate ( $\text{Na}_2\text{SO}_4$ ), stopper the flask, shake, and let stand at a temperature below 25° C. until the ethereal liquid becomes perfectly clear, showing that all water has been taken up by the sodium sulphate. Filter through a dry paper into another Erlenmeyer flask and completely evaporate off the ether by passing through the flask a current of dry air while heating the flask to a temperature not above 50° C.

(2) *Determination*.—In a 250 cc Erlenmeyer flask dissolve about 2 g of the fatty acids accurately weighed in 20 to 30 cc of neutral 95 per cent ethyl alcohol. Titrate with standard alkali, using phenolphthalein as indicator. Calculate the acid number (mg of  $\text{KOH}$  per g of fatty acids).

(f) *ROSIN*.—A qualitative test for rosin may be made as follows: After decomposing a solution of the soap and separating the fatty acids heat a small quantity of the latter with acetic anhydride, cool, place a few drops on a spot plate, and add a drop of  $\text{H}_2\text{SO}_4$  (specific gravity = 1.53) to this. A fugitive violet color indicates the presence of rosin.

(g) SUGAR.—A qualitative test for sugar may be made as follows: Add a decided excess of hydrochloric acid to a solution of the soap, heat on a steam bath for 15 minutes, cool, filter from fatty acids, and test a portion of the filtrate, which has been neutralized with sodium hydroxide solution, by boiling for two minutes with an equal volume of boiling Fehling solution. The formation of red cuprous oxide indicates the presence of sugar.

#### 4. REAGENTS.

(a) STANDARD SODIUM HYDROXIDE SOLUTION.—0.25 N, or about 10 g sodium hydroxide dissolved in water and diluted to 1 liter. Standardized against Bureau of Standards benzoic acid.

(b) STANDARD SULPHURIC ACID SOLUTION.—0.5 N, or about 25.8 g strong sulphuric acid (specific gravity = 1.84) diluted to 1 liter. Standardized against standard sodium hydroxide solution (a).

(c) STANDARD SILVER NITRATE SOLUTION.—0.10 N, or about 17 g of silver nitrate dissolved in water and diluted to 1 liter. Standardized against chemically pure sodium chloride.

(d) SULPHURIC ACID (SPECIFIC GRAVITY = 1.53).—Mix 62.5 cc of strong sulphuric acid (specific gravity = 1.84) with 61.5 cc of water.

(e) FEHLING SOLUTION.—(1) *Copper Sulphate Solution*.—Dissolve 34.639 g of copper sulphate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) in water and dilute to 500 cc.

(2) *Alkaline Tartrate Solution*.—Dissolve 173 g of Rochelle salts ( $\text{NaK}_6\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$ ) and 50 g of sodium hydroxide in water and dilute to 500 cc. Mix equal volumes of (1) and (2) immediately before use.

(f) POTASSIUM CHROMATE SOLUTION.—A 10 per cent solution of potassium chromate ( $\text{K}_2\text{CrO}_4$ ) in water.

(g) STANDARD ALCOHOLIC SODIUM HYDROXIDE SOLUTION.—Same as (a), excepting that ethyl alcohol (94 per cent or higher) is used instead of water.

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" S. W. STRATTON, Director.

## CIRCULAR OF THE BUREAU OF STANDARDS.

## No. 124.

(Issued July 27, 1922.)

UNITED STATES GOVERNMENT SPECIFICATION FOR  
LIQUID SOAP.

## FEDERAL SPECIFICATIONS BOARD.

## STANDARD SPECIFICATION No. 27.

This Specification was officially adopted by the Federal Specifications Board on June 20, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of materials covered by it.

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## 1. GENERAL.

The soap desired under this specification is a clear solution of pure vegetable oil potash (or potash and soda) soap with or without glycerol or alcohol, suitably perfumed, and free from all foreign matter. It should quickly form a satisfactory lather and have no injurious effect and leave no objectionable odor on the skin. Bidder shall state number of gallons to the container.

Failure to meet any of the following requirements will be cause for rejection:

The material must be a clear solution, free from objectionable odor, other than from coconut oil, and must quickly form a satisfactory lather.

Total anhydrous soap shall be not less than the equivalent of 15 per cent potash soap.

Total matter insoluble in alcohol shall not exceed 0.5 per cent.

Free alkali calculated as potassium hydroxide (KOH) shall not exceed 0.05 per cent.

Chloride calculated as potassium chloride (KCl) shall not exceed 0.3 per cent.

More than traces of sulphates and sugar shall not be present.

All constituents shall be calculated on the basis of the original sample.

The material will be purchased by volume in accordance with the contract agreement. A gallon of soap shall mean 231 cubic inches at 15.5° C.

## 2. SAMPLING.

A sample of not less than one-half pint shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 10 gallons each. In case of smaller containers a sample of not less than one-half pint shall be taken at random from each lot of containers totaling not to exceed 1,000 gallons. The total sample shall in all cases consist of not less than three portions of one-half pint each taken at random from separate containers. Before drawing the sample from the container selected the contents of the container shall be thoroughly agitated. The inspector shall thoroughly mix the samples drawn, place in clean, dry cans or bottles, which shall be completely filled and securely stoppered with clean corks or caps, seal, mark, and send to the laboratory for test. The seller shall have the option of being represented at the time of sampling and when he so requests shall be furnished with a duplicate sample.

## 3. LABORATORY EXAMINATION.

(a) PREPARATION OF SAMPLE.—No preparation of the sample, other than thorough mixing, is necessary unless it is received during very cold weather, when it should be allowed to stand at least one hour after it has warmed up to room temperature (20° to 30° C.) before it is noted whether it forms a satisfactory lather.

When a determination shows nonconformity with specification, a duplicate shall be run.

(b) TOTAL ANHYDROUS SOAP.—Dissolve 10 g of the sample in 100 cc of water in a 250 cc Erlenmeyer flask. When solution is complete, add dilute sulphuric acid in slight excess, insert a small funnel in the neck of the flask, and heat the flask at a temperature not exceeding 60° C. until the fatty acids separate as a clear layer. Transfer to a separatory funnel, draw off the acid layer into a second separatory funnel, and shake the acid aqueous liquid with two 20 cc portions of ethyl ether. Dissolve the fatty acids in the ether used for washing the aqueous liquid and shake with 10 cc portions of water until they are no longer acid to

methyl orange. Unite the water portions used for washing and shake with 20 cc of ether, wash this ether until the wash water is neutral to methyl orange. Unite the ether solutions (if necessary, filter, washing the paper with ether) in a suitable weighed vessel, add 100 cc of neutral alcohol free from carbon dioxide, add phenolphthalein and titrate to exact neutrality with standard sodium hydroxide solution. Evaporate off the alcohol, dry to constant weight as in the determination of matter volatile at  $105^{\circ}$  C., and calculate the percentage of soda soap. This soap naturally includes any mineral oil and neutral fat, which, if determined separately, must be deducted from the result to obtain the true soap. Calculate the combined sodium oxide ( $\text{Na}_2\text{O}$ ) and deduct from the weight of soda soap to give the anhydrides. If the original soap was potash soap, proper calculation must be made to reduce to potassium oxide ( $\text{K}_2\text{O}$ ) or the titration made directly with standard potassium hydroxide solution. In case the soap shows an excess of free acid, proper corrections must be made in calculating the combined alkali in the original soap. (A blank test should be made on the sodium or potassium hydroxide solution for neutral salts and the proper corrections made if necessary.)

(c) TOTAL MATTER INSOLUBLE IN ALCOHOL. FREE ALKALI, OR FREE ACID.—(1) *Matter Insoluble in Alcohol*.—Digest hot a 10 g sample with 200 cc of freshly boiled neutral ethyl alcohol (94 per cent or higher). Filter through a counterpoised filter paper neutral to phenol-phthalein, or a weighed Gooch crucible with suction, protecting the solution during the operation from carbon dioxide and other acid fumes. Wash the residue on the paper or in the crucible with hot neutral alcohol until free from soap. Dry the filter paper or crucible and residue at  $100^{\circ}$  to  $105^{\circ}$  C. for three hours, cool, and weigh the total matter insoluble in alcohol.

(2) *Free Alkali or Free Acid*.—Titrate the filtrate from the above, using phenolphthalein as indicator, with standard acid or alkali solution, and calculate the alkalinity to sodium hydroxide (or potassium hydroxide) or acidity to oleic acid.

(d) CHLORIDE.—Dissolve 10 g of the sample in 300 cc of water, boiling if necessary to effect solution of all soluble matter. Add an excess of neutral chlorine-free magnesium nitrate solution (about 25 cc of a 20 per cent  $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$  solution). Without cooling or filtering titrate with standard silver nitrate solution, using potassium chromate as indicator. Calculate the chloride as potassium chloride.

(e) **SULPHATE.**—A qualitative test may be made as follows: Proceed as in the determination of alcohol insoluble until the insoluble matter has been thoroughly washed in a Gooch crucible or on a filter paper with hot alcohol. Dissolve this insoluble matter in hot water, acidify with hydrochloric acid, and evaporate to dryness. Take up with a small amount of hydrochloric acid and water, filter, and test for sulphate.

(f) **SUGAR.**—A qualitative test may be made as follows: Add a decided excess of hydrochloric acid to a solution of the soap, heat on a steam bath for 15 minutes, cool, filter from fatty acids, and test a portion of the filtrate, which has been neutralized with sodium hydroxide solution, by boiling for two minutes with an equal volume of boiling Fehling solution. The formation of red cuprous oxide indicates the presence of sugar.

#### 4. REAGENTS.

(a) **STANDARD SODIUM HYDROXIDE SOLUTION.**—0.25N, or about 10 g sodium hydroxide dissolved in water and diluted to 1 liter. Standardized against Bureau of Standards benzoic acid.

(b) **STANDARD SULPHURIC ACID.**—0.5 N, or about 25.8 g strong sulphuric acid (specific gravity = 1.84) diluted with water to 1 liter. Standardized against standard sodium hydroxide solution (a).

(c) **STANDARD ALCOHOLIC POTASSIUM HYDROXIDE SOLUTION.**—0.25 N or about 14 g of potassium hydroxide dissolved in neutral ethyl alcohol (94 per cent or higher) and diluted to 1 liter with alcohol. Standardized against Bureau of Standards benzoic acid.

(d) **STANDARD ALCOHOLIC SODIUM HYDROXIDE SOLUTION.**—Same as (a) excepting that (94 per cent or higher) ethyl alcohol is used instead of water. Standardized against benzoic acid.

(e) **STANDARD SILVER NITRATE SOLUTION.**—0.10 N, or about 17 g of silver nitrate dissolved in water and diluted to 1 liter. Standardized against chemically pure sodium chloride.

(f) **POTASSIUM CHROMATE SOLUTION.**—A 10 per cent solution of potassium chromate in water.

(g) **FEHLING SOLUTION.**—(1) *Copper Sulphate Solution.*—Dissolve 34.639 g of copper sulphate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) in water and dilute to 500 cc.

(2) *Alkaline Tartrate Solution.*—Dissolve 173 g of Rochelle salts ( $\text{NaKC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$ ) and 50 g of sodium hydroxide in water and dilute to 500 cc. Mix equal volumes of (1) and (2) immediately before use.

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DEPARTMENT OF COMMERCE.

U.S. BUREAU OF STANDARDS.

S. W. STRATTON, Director.

CIRCULAR OF THE BUREAU OF STANDARDS.

No. 125.

Issued July 27, 1922.

UNITED STATES GOVERNMENT SPECIFICATION FOR  
SOAP POWDER.

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION No. 28.

This Specification was officially adopted by the Federal Specifications Board on June 20, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of materials covered by it.

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1. GENERAL.

The material desired under this specification is a uniform mixture of soap and sodium carbonate in powdered form. It should be readily soluble in tepid water and should contain no free caustic alkali or inert fillers. Bidder shall state size and number of pounds to the package.

Failure to meet any of the following requirements will be cause for rejection.

Anhydrous soap shall be not less than 15 per cent.

Sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) shall be not less than 30 per cent. (The aggregate of anhydrous soap and sodium carbonate shall be not less than 55 per cent.)

Material will be purchased by net weight.

## 2. SAMPLING.

(a) **WHEN PACKED IN CANS OR CARTONS.**—One can or carton shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 50 pounds each. In the case of smaller containers a can or carton shall be taken at random from each lot of containers totaling not to exceed 5,000 pounds. The total sample shall in all cases consist of not less than three cans or cartons taken at random from separate containers. With very large lots where the sample drawn as above will amount to more than 20 pounds the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds. Wrap the individual cans or cartons tightly in paraffined paper at once and seal by rubbing the edges with a heated iron. The inspector should accurately weigh each wrapped can or carton, record its weight and the date of weighing on the wrapper, place the wrapped cans or cartons in an air-tight container, which should be nearly filled, seal, mark, and send to the laboratory for test. Samples should be kept cool until tested. The seller shall have the option of being represented at the time of sampling, and when he so requests shall be furnished with a duplicate sample.

(b) **WHEN IN BULK.**—A grab sample of not less than one-half pound shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 100 pounds each. In case of smaller containers a grab sample of not less than one-half pound shall be taken at random from each lot of containers totaling not to exceed 10,000 pounds. The total sample shall in all cases consist of not less than three grab portions taken at random from separate containers. With very large lots where the sample drawn as above will amount to more than 20 pounds the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds. The inspector should rapidly mix the sample, place in an air-tight container, which shall be filled, seal, mark, accurately weigh, record its weight and date of weighing on the package, and send to the laboratory for test. Samples should be kept cool until tested. The seller shall have the option of being represented at the time of sampling, and when he so requests shall be furnished with a duplicate sample.

### 3. LABORATORY EXAMINATION.

(a) PREPARATION OF SAMPLE.—Rapidly disintegrate and mix the sample, if desired quarter down to about 1 pound, and weigh out all portions for analysis at once. Unused portions of the sample used for analysis shall be preserved in an air-tight container in a cool place.

When a determination shows nonconformity with specification, a duplicate shall be run.

(b) ANHYDROUS SOAP.—Dissolve 5 g of the sample in about 200 cc of freshly boiled neutral (94 per cent or higher) ethyl alcohol, heating to complete the solution. Filter into a weighed beaker, and wash with hot, freshly boiled neutral alcohol. Evaporate the filtrate to dryness, dry at 105° C. to constant weight, and calculate as anhydrous soap.

(c) SODIUM CARBONATE.—Extract with hot water the matter insoluble in alcohol which is separated during the determination of anhydrous soap, add methyl orange to the water solution and titrate with standard acid, and calculate the percentage of sodium carbonate ( $\text{Na}_2\text{CO}_3$ ).

### 4. REAGENTS.

(a) STANDARD SULPHURIC ACID SOLUTION.—0.5 N, or about 25.8 g strong sulphuric acid (specific gravity = 1.84) diluted to 1 liter. Standardized against standard sodium hydroxide solution (b).

(b) STANDARD SODIUM HYDROXIDE SOLUTION.—0.25 N, or about 10 g sodium hydroxide dissolved in water and diluted to 1 liter. Standardized against Bureau of Standards benzoic acid.

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S. W. STRATTON, Director.

CIRCULAR OF THE BUREAU OF STANDARDS.

No. 126.

(Issued July 27, 1922.)

UNITED STATES GOVERNMENT SPECIFICATION FOR  
SALT WATER SOAP.

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION No. 29.

This Specification was officially adopted by the Federal Specifications Board on June 20, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of materials covered by it.

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1. GENERAL.

The soap desired under this specification is a soap well made from pure coconut oil and the necessary alkali. It must be entirely soluble in both sea water and fresh water and make a suitable lather. Bidder shall state size, weight, and number of cakes in each box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 55 per cent.

Deliveries which yield more than 55 per cent of volatile matter will be rejected without further test.

Total matter insoluble in alcohol shall be not less than 2 per cent nor more than 3 per cent and shall consist, essentially, of sodium carbonate ( $\text{Na}_2\text{CO}_3$ ).

Free alkali, calculated as sodium hydroxide ( $\text{NaOH}$ ) shall not exceed 0.5 per cent.

Matter insoluble in water shall not exceed 0.5 per cent.

Chloride, calculated as sodium chloride ( $\text{NaCl}$ ), shall be not less than 2.5 per cent nor more than 3.5 per cent.

Rosin, sugar, and foreign matter shall not be present.

The acid number of the mixed fatty acids prepared from the soap shall be not less than 250.

The percentage of matter volatile at  $105^\circ \text{C}$ . will be computed on the basis of the soap as received, but all other constituents will be calculated on the basis of material containing 55 per cent of volatile matter. The material will be purchased by net weight.

## 2. SAMPLING.

One cake shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 50 pounds each. In the case of smaller containers a cake shall be taken at random from each lot of containers totaling not to exceed 5,000 pounds. The total sample shall in all cases consist of not less than three cakes taken at random from separate containers. With very large lots where the samples drawn as above will amount to more than 20 pounds the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds.

Wrap the individual cakes tightly in paraffined paper at once and seal by rubbing the edges with a heated iron. The inspector should accurately weigh each wrapped cake, record its weight and the date of weighing on the wrapper, place the wrapped cakes in an air-tight container, which should be nearly filled, seal, mark, and send to the laboratory for test. Samples should be kept cool until tested. The seller shall have the option of being represented at the time of sampling and when he so requests shall be furnished with a duplicate sample.

## 3. LABORATORY EXAMINATION.

(a) PREPARATION OF SAMPLE.—In case of samples that can be easily disintegrated and mixed, run the entire sample through a suitable chopper, except where the sample is large, when each

cake may be quartered and one-quarter of each cake run through the chopper. With samples that can not be handled as above, select a cake of average weight, quarter by cutting at right angles in the center, and shave equally from all freshly cut surfaces sufficient soap for analysis. Mix and weigh out all portions for analysis promptly. Preserve the remainder in an air-tight container in a cool place.

When a determination shows nonconformity with specification, a duplicate shall be run.

(b) **MATTER VOLATILE AT 105° C.**—Weigh 5 g of the sample in a porcelain or glass dish, about 6 to 7 cm in diameter and 4 cm deep, dry to constant weight in a vacuum oven or an inert atmosphere at a temperature not exceeding 105° C. (Time can be saved by having a layer of about 3 mm of ignited sand and a small stirring rod weighed with the dish and dissolving the sample in absolute alcohol, evaporating to dryness, breaking up sample with the rod, adding more alcohol, again evaporating and completing the drying in the oven as above.) Report loss in weight as matter volatile at 105° C.

(c) **TOTAL MATTER INSOLUBLE IN ALCOHOL, FREE ALKALI, OR FREE ACID.**—(1) *Matter Insoluble in Alcohol.*—Digest hot a 10 g sample with 200 cc of freshly boiled neutral ethyl alcohol (94 per cent or higher). Filter through a counterpoised filter paper neutral to phenolphthalein, or a weighed Gooch crucible with suction, protecting the solution during the operation from carbon dioxide and other acid fumes. Wash the residue on the paper or in the crucible with hot neutral alcohol until free from soap. Dry the filter paper or crucible and residue at 100° to 150° C. for three hours, cool, and weigh the total matter insoluble in alcohol.

(2) *Free Alkali or Free Acid.*—Titrate the filtrate from the above, using phenolphthalein as indicator, with standard acid or alkali solution, and calculate the alkalinity to sodium hydroxide (or potassium hydroxide) or acidity to oleic acid.

(3) *Matter Insoluble in Water.*—Proceed as in the determination of matter insoluble in alcohol. After filtering and thoroughly washing the residue extract it with water at 60° C. and wash the filter thoroughly. (When the matter insoluble in water is all inorganic, boiling water may be used for the extraction and washing.) Dry the filter and residue at 100° to 105° C. for three hours, cool, and weigh matter insoluble in water. The nature of this may be determined by further examination.

(4) *Total Alkalinity of Matter Insoluble in Alcohol (Alkaline Salts).*—Titrate the filtrate from the determination of matter insoluble in water with standard acid, using methyl orange as indicator. Calculate alkalinity to sodium carbonate ( $\text{Na}_2\text{CO}_3$ ).

(d) *CHLORIDE.*—Dissolve 5 g of the sample in 300 cc of water, boiling if necessary to effect solution of all soluble matter. Add an excess of neutral chlorine-free magnesium nitrate solution (about 25 cc of a 20 per cent  $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$  solution). Without cooling or filtering titrate with standard silver nitrate solution, using potassium chromate as indicator. Calculate the chloride as sodium chloride.

(e) *ROSIN.*—A qualitative test for rosin may be made as follows: After decomposing a solution of the soap and separating the fatty acids heat a small quantity of the latter with acetic anhydride, cool, place a few drops on a spot plate, and add a drop of  $\text{H}_2\text{SO}_4$  (specific gravity = 1.53). A fugitive violet color indicates the presence of rosin.

(f) *SUGAR.*—A qualitative test for sugar may be made as follows: Add a decided excess of hydrochloric acid to a solution of the soap, heat on a steam bath for 15 minutes, cool, filter from fatty acids, and test a portion of the filtrate which has been neutralized with sodium hydroxide solution by boiling for two minutes with an equal volume of boiling Fehling solution. The formation of red cuprous oxide indicates the presence of sugar.

(g) *ACID NUMBER.*—(1) *Preparation of Fatty Acids.*—Dissolve about 50 g of the soap in 300 cc of hot water, transfer to a separatory funnel, add 150 cc of approximately 2N  $\text{H}_2\text{SO}_4$ , cool somewhat, add 120 cc of ether, shake, draw off the acid layer, and wash the ether layer free from acid with a strong salt ( $\text{NaCl}$ ) solution. Then draw off the aqueous layer as completely as possible, transfer the ether layer to a flask (it is not necessary to transfer quantitatively), and 20 to 30 g of anhydrous sodium sulphate ( $\text{Na}_2\text{S}_2\text{O}_4$ ), stopper the flask, shake, and let stand at a temperature below 25° C. until the ethereal liquid becomes perfectly clear, showing that all water has been taken up by the sodium sulphate. Filter through a dry paper into another Erlenmeyer flask and completely evaporate off the ether by passing through the flask a current of dry air, while heating the flask to a temperature not above 50° C.

(2) *Determination.*—In a 250 cc Erlenmeyer flask dissolve about 2 g of the fatty acids accurately weighed in 20 to 30 cc

of neutral 95 per cent ethyl alcohol. Titrate with standard alkali, using phenolphthalein as indicator. Calculate acid number (mg of KOH per g of fatty acids).

#### 4. REAGENTS.

(a) STANDARD SODIUM HYDROXIDE SOLUTION.—0.25 N, or about 10 g sodium hydroxide dissolved in water and diluted to 1 liter. Standardized against Bureau of Standards' benzoic acid.

(b) STANDARD SULPHURIC ACID SOLUTION.—0.5 N, or about 25.8 g strong sulphuric acid (specific gravity=1.84) diluted to 1 liter. Standardized against standard sodium hydroxide solution (a).

(c) STANDARD SILVER NITRATE SOLUTION.—0.10 N, or about 17 g of silver nitrate dissolved in water and diluted to 1 liter. Standardized against chemically pure sodium chloride.

(d) SULPHURIC ACID (SPECIFIC GRAVITY=1.53).—Mix 62.5 cc of strong sulphuric acid (specific gravity=1.84) with 61.5 cc of water.

(e) STANDARD ALCOHOLIC SODIUM HYDROXIDE SOLUTION.—Same as (a), excepting that 95 per cent ethyl alcohol is used instead of water.

(f) POTASSIUM CHROMATE SOLUTION.—A 10 per cent solution of potassium chromate in water.

(g) FEHLING SOLUTION.—(1) *Copper Sulphate Solution*.—Dissolve 34.639 g of copper sulphate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) in water and dilute to 500 cc.

(2) *Alkaline Tartrate Solution*.—Dissolve 173 g of Rochelle salts ( $\text{NaKC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$ ) and 50 g of sodium hydroxide in water and dilute to 500 cc. Mix equal volumes of (1) and (2) immediately before use.

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S. W. STRATTON, Director.

CIRCULAR OF THE BUREAU OF STANDARDS.

No. 127.

(Issued July 27, 1922.)

UNITED STATES GOVERNMENT SPECIFICATION FOR  
AUTOMOBILE SOAP.

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION No. 30.

This Specification was officially adopted by the Federal Specifications Board on June 20, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of materials covered by it.

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1. GENERAL.

The soap desired under this specification is a pure vegetable oil paste soap containing no free alkali or acid, relatively free from matter insoluble in alcohol, homogeneous, free from adulterants of any kind, and without objectionable odor. Bidder to state size and weight of unit.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 55 per cent. Deliveries which yield more than 55 per cent of volatile matter will be rejected without further test.

The sum of free alkali and total matter insoluble in alcohol shall not exceed 1 per cent.

Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.2 per cent.

Free acid, calculated as oleic, shall not exceed 0.2 per cent.

Matter insoluble in water shall not exceed 0.2 per cent.

Unsaponified matter shall not exceed 4 per cent.

Rosin shall not be present.

Odor must be as specified in contract.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constituents will be calculated on the basis of material containing 50 per cent of volatile matter.

The material will be purchased by net weight.

## 2. SAMPLING.

(a) WHEN PACKED IN CANS OR CARTONS OF 5 POUNDS OR LESS.—One can or carton shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 50 pounds each. In case of smaller containers a can or carton shall be taken at random from each lot of containers totaling not to exceed 5,000 pounds. The total sample shall in all cases consist of not less than three cans or cartons taken at random from separate containers. With very large lots where the sample drawn as above will amount to more than 20 pounds the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds. Wrap, seal, mark, and send to laboratory for test.

(b) WHEN PACKED IN BULK.—Take at random a trier sample of not less than one-half pound from not less than 1 per cent of the vendors' shipping containers, provided such containers do not contain less than 50 pounds each. In case of smaller containers a trier sample shall be taken at random from each lot of containers totaling not to exceed 5,000 pounds. The total sample shall in all cases consist of not less than 3 half-pound portions taken at random from separate containers. With very large lots where the sample drawn as above will amount to more than 10 pounds the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 10 pounds. The inspector shall promptly place the combined sample in a clean, dry, air and water tight container, which shall be filled, seal, mark, and send to the laboratory for test. The seller shall have the option of being represented at the time of sampling and when he so requests shall be furnished with a duplicate sample.

## 3. LABORATORY EXAMINATION.

(a) PREPARATION OF SAMPLE.—Mix thoroughly by kneading and quarter down to about 1 pound. Weigh out all portions for analysis promptly and preserve the remainder in an air-tight container in a cool place.

When a determination shows nonconformity with specifications, a duplicate shall be run.

(b) **MATTER VOLATILE AT 105° C.**—Weigh 5 g of the sample in a porcelain or glass dish, about 6 to 7 cm in diameter and 4 cm deep, dry to constant weight in a vacuum oven or an inert atmosphere at a temperature not exceeding 105° C. (Time can be saved by having a layer of about 3 mm of ignited sand and a small stirring rod weighed with the dish and dissolving the sample in absolute alcohol, evaporating to dryness, breaking up the sample with the rod, adding more alcohol, again evaporating and completing the drying in the oven as above.) Report loss in weight as matter volatile at 105° C.

(c) **TOTAL MATTER INSOLUBLE IN ALCOHOL. FREE ALKALI OR FREE ACID.**—(1) *Matter Insoluble in Alcohol.*—Digest hot a 10 g sample with 200 cc of freshly boiled neutral ethyl alcohol (94 per cent or higher). Filter through a counterpoised filter paper neutral to phenolphthalein, or a weighed Gooch crucible with suction, protecting the solution during the operation from carbon dioxide and other acid fumes. Wash the residue on the paper or in the crucible with hot neutral alcohol until free from soap. Dry the filter paper or crucible and residue at 100 to 105° C. for three hours, cool, and weigh the total matter insoluble in alcohol.

(2) *Free Alkali or Free Acid.*—Titrate the filtrate from the above, using phenolphthalein as indicator, with standard acid or alkali solution, and calculate the alkalinity to sodium hydroxide (or potassium hydroxide) or acidity to oleic acid.

(3) *Matter Insoluble in Water.*—Proceed as in the determination of matter insoluble in alcohol. After filtering and thoroughly washing the residue extract it with water at 60° C. and wash the filter thoroughly. (When the matter insoluble in water is all inorganic, boiling water may be used for the extraction and washing.) Dry the filter and residue at 100 to 105° C. for three hours, cool, and weigh matter insoluble in water. The nature of this may be determined by further examination.

(d) **UNSAAPONIFIED MATTER.**—In a beaker on the steam bath dissolve 5 g of the soap in about 100 cc of 50 per cent alcohol. If the sample has been found to contain free fatty acid, add just enough aqueous alkali to neutralize this. Evaporate off the bulk of the alcohol, take up with about 200 cc of hot water, and transfer to a separatory funnel of about 500 cc capacity, designated as No. 1. When cool, rinse out the beaker with about 50 cc of ether and add it to the soap solution. Shake thoroughly for one minute. By the addition of small amounts of alcohol

(5 cc portions and the total not to exceed 25 cc) a clear and rapid separation of the aqueous and ether layers is effected. After adding each alcohol portion the separatory funnel is not shaken but merely given a whirling movement. Draw off the aqueous portion into another separatory funnel, designated as No. 2. Wash the ether solution with 10 cc portions of water until this water is no longer alkaline to phenolphthalein. Add all of these washings to funnel No. 2 and extract this solution with 20 cc portions of ether until the ether is absolutely colorless (three or four extractions should be sufficient). Combine these ether extracts in a third separatory funnel (No. 3) and wash with 10 cc portions of water until the water is no longer alkaline to phenolphthalein. Now add the ether in funnel No. 3 to that in funnel No. 1, a small amount of ether being used to rinse out funnel No. 3. Wash the ether solution with 20 cc of 10 per cent hydrochloric acid solution and then successively with 20 cc portions of water until the water is no longer acid to methyl orange. Filter the ether solution through a dry filter paper into a weighed beaker or flask. Evaporate or distill off the ether on the steam bath, dry as under the determination of matter volatile at  $105^{\circ}$  C., and weigh the residue. Then heat with alcohol and when cool neutralize with standard alkali, using phenolphthalein. Deduct any appreciable amount of fatty acid found by this titration from the weight of the residue.

(e) ROSIN.—A qualitative test for rosin may be made as follows: After decomposing a solution of the soap and separating the fatty acids heat a small quantity of the latter with acetic anhydride, cool, place a few drops on a spot plate and add a drop of  $\text{H}_2\text{SO}_4$  (specific gravity = 1.53) to this. A fugitive violet color indicates the presence of rosin.

#### 4. REAGENTS.

(a) STANDARD SODIUM HYDROXIDE SOLUTION.—0.25 N, or about 10 g sodium hydroxide dissolved in water and diluted to 1 liter. Standardized against Bureau of Standards benzoic acid.

(b) STANDARD SULPHURIC ACID SOLUTION.—0.5 N, or about 25.8 g strong sulphuric acid (specific gravity = 1.84) diluted to 1 liter. Standardized against standard sodium hydroxide solution (a).

(c) SULPHURIC ACID (SPECIFIC GRAVITY = 1.53).—Mix 62.5 cc of strong sulphuric acid (specific gravity = 1.84) with 61.5 cc of water.

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DEPARTMENT OF COMMERCE.

U.S. BUREAU OF STANDARDS.

" S. W. STRATTON, Director.

CIRCULAR OF THE BUREAU OF STANDARDS.

No. 128.

(Issued July 27, 1922.)

UNITED STATES GOVERNMENT SPECIFICATION FOR  
CHIP SOAP.

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION No. 31.

This Specification was officially adopted by the Federal Specifications Board on June 20, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of materials covered by it.

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1. GENERAL.

The soap desired under this specification is a soap in chip form made from soda and fats, without rosin, as free as possible from water and all substances other than true soap, of a light uniform color, free from disagreeable odor, and suitable for high grade laundry work with soft water, when the presence of alkaline salts is objectionable. Bidder shall state size and weight of package.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 15 per cent. Deliveries which yield more than 15 per cent of volatile matter will be rejected without further test.

Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.5 per cent.

Matter insoluble in water shall not exceed 0.2 per cent.

Titer of the mixed fatty acids prepared from the soap must be not less than 39° C.

Color and odor must be as specified.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constituents will be calculated on the basis of material containing 10 per cent of volatile matter.

The material will be purchased by net weight, provided the matter volatile at 105° C. does not exceed 10 per cent. With deliveries containing more than 10 per cent but not exceeding 15 per cent of matter volatile at 105° C. settlement will be made on the basis of 10 per cent of matter volatile at 105° C.; that is, nine-tenths of a pound of nonvolatile matter will be considered 1 pound of soap.

*Examples.*—1. Yield 6 per cent of matter volatile at 105° C.; pay for net weight.

2. Yield 12 per cent of matter volatile at 105° C.; percentage of net weight to be paid for is calculated as follows:

$$(100 - 12) \times 10/9 = 97.8 \text{ per cent.}$$

## 2. SAMPLING.

(a) No samples shall be submitted with bids.

(b) WHEN PACKED IN CANS OR CARTONS.—One can or carton shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 50 pounds each. In the case of smaller containers a can or carton shall be taken at random from each lot of containers totaling not to exceed 5,000 pounds. The total sample shall in all cases consist of not less than three cans or cartons taken at random from separate containers. With very large lots where the sample drawn as above will amount to more than 20 pounds the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds.

Wrap the individual cans or cartons tightly in paraffined paper at once and seal by rubbing the edges with a heated iron. The inspector should accurately weigh each wrapped can or carton, record its weight and the date of weighing on the wrapper, place the wrapped cans or cartons in an air-tight container, which should

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be nearly filled, seal, mark, and send to the laboratory for test. Samples should be kept cool until tested. The seller shall have the option of being represented at the time of sampling and when he so requests shall be furnished with a duplicate sample.

(c) **WHEN IN BULK.**—A grab sample of not less than one-half pound shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 100 pounds each. In case of smaller containers a grab sample of not less than one-half pound shall be taken at random from each lot of containers totaling not to exceed 10,000 pounds. The total sample shall in all cases consist of not less than three grab portions taken at random from separate containers. With very large lots where the sample drawn as above will amount to more than 20 pounds the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds. The inspector should rapidly mix the sample, place in an air-tight container, which shall be filled, seal, mark, accurately weigh, record its weight and date of weighing on the package, and send to the laboratory for test. Samples should be kept cool until tested. The seller shall have the option of being represented at the time of sampling, and when he so requests shall be furnished with a duplicate sample.

### 3. LABORATORY EXAMINATION.

(a) **PREPARATION OF SAMPLE.**—Rapidly disintegrate and mix the sample, if desired quarter down to about 1 pound, and weigh out all portions for analysis at once. Unused portions of the sample used for analysis shall be preserved in an air-tight container in a cool place.

When a determination shows nonconformity with specification, a duplicate shall be run.

(b) **MATTER VOLATILE AT 105° C.**—Weigh 5 g of the sample in a porcelain or glass dish, about 6 or 7 cm in diameter and 4 cm deep, dry to constant weight in an inert atmosphere at a temperature not exceeding 105° C. (Time can be saved by having a layer of about 3 mm of ignited sand and a small stirring rod weighed with the dish and dissolving the sample in absolute alcohol, evaporating to dryness, breaking up the sample with the rod, adding more alcohol, again evaporating, and completing the drying in the oven as above.) Report loss in weight as matter volatile at 105° C.

(c) **TOTAL MATTER INSOLUBLE IN ALCOHOL. FREE ALKALI OR FREE ACID.**—(1) *Matter Insoluble in Alcohol.*—Digest hot a 10 g sample with 200 cc of freshly boiled neutral ethyl alcohol (94 per cent or higher). Filter through a counterpoised filter paper neutral to phenolphthalein, or a weighed Gooch crucible with suction, protecting the solution during the operation from carbon dioxide and other acid fumes. Wash the residue on the paper or in the crucible with hot neutral alcohol until free from soap. Dry the filter paper or crucible and residue at 100 to 105° C. for three hours, cool and weigh the total matter insoluble in alcohol.

(2) *Free Alkali or Free Acid.*—Titrate the filtrate from above, using phenolphthalein as indicator, with standard acid or alkali solution and calculate the alkalinity to sodium hydroxide (or potassium hydroxide) or acidity to oleic acid.

(3) *Matter Insoluble in Water.*—Proceed as in the determination of matter insoluble in alcohol. After filtering and thoroughly washing the residue extract it with water at 60° C. and wash the filter thoroughly. (When the matter insoluble in water is all inorganic, boiling water may be used for extraction and washing.) Dry the filter and residue at 100 to 105° C. for three hours, cool, and weigh matter insoluble in water. The nature of this may be determined by further examination.

(d) **CHLORIDE.**—Dissolve 5 g of the sample in 300 cc of water, boiling if necessary to effect solution of all soluble matter. Add an excess of neutral chlorine-free magnesium nitrate solution (about 25 cc of a 20 per cent  $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$  solution). Without cooling or filtering titrate with standard silver nitrate solution, using potassium chromate as indicator. Calculate the chloride as sodium chloride.

(e) **TITER TEST.**—(1) *Preparation of Total Fatty Matter.*—Dissolve about 50 g of soap in 500 cc of hot water, add 100 cc of 30 per cent sulphuric acid, heat until the fatty matter collects in a clear layer, draw off the acid layer and wash the fatty matter free from sulphuric acid with hot water. Decant the fatty matter into a dry beaker, filter, using a hot-water funnel, or placing both funnel and receiving beaker in a water-jacketed oven, and dry for 20 minutes at the temperature of boiling water.

(2) *Determination.*—Cool the fatty acids, prepared as described, to about 50° C. and transfer about 25 cc to a tube of clear glass about 1 mm thick, 25 mm in diameter, and 100 mm long. Place the tube in a salt-mouth bottle about 70 mm in diameter and 15 mm high (a 16-ounce salt-mouth bottle), fitted with a cork which

and 15 mm high (a 16-ounce salt-mouth bottle), fitted with a cork which is perforated so as to hold the tube rigidly when in position. Suspend a thermometer graduated to  $0.1^{\circ}\text{C.}$ , so that it can be used as a stirrer and stir the mass slowly, first in one direction and then in the other, being careful not to touch the side of the tube, until the mercury remains stationary for 30 seconds. Then allow the thermometer to hang quietly, with the bulb in the center of the mass, and observe the rise of the mercury. The highest point to which it rises is recorded as "titer."

(f) ROSIN.—A qualitative test for rosin may be made as follows: After decomposing a solution of the soap and separating the fatty acids heat a small quantity of the latter with acetic anhydride, cool, place a few drops on a spot plate, and add a drop of  $\text{H}_2\text{SO}_4$  (specific gravity = 1.53) to this. A fugitive violet color indicates the presence of rosin.

#### 4. REAGENTS.

(a) STANDARD SODIUM HYDROXIDE SOLUTION.—0.25 N, or about 10 g. sodium hydroxide dissolved in water and diluted to 1 liter. Standardized against Bureau of Standards benzoic acid.

(b) STANDARD SULPHURIC ACID SOLUTION.—0.5 N, or about 25.8 g strong sulphuric acid (specific gravity = 1.84) diluted to 1 liter. Standardized against standard sodium hydroxide solution (a).

(c) STANDARD SILVER NITRATE SOLUTION.—0.10 N, or about 17 g of silver nitrate dissolved in water and diluted to 1 liter. Standardized against chemically pure sodium chloride.

(d) POTASSIUM CHROMATE SOLUTION.—A 10 per cent solution of potassium chromate ( $\text{K}_2\text{CrO}_4$ ) in water.

(e) SULPHURIC ACID (SPECIFIC GRAVITY = 1.53).—Mix 62.5 c c of strong sulphuric acid (specific gravity = 1.84) with 61.5 c c of water.

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DEPARTMENT OF COMMERCE.  
U.S. BUREAU OF STANDARDS.  
S. W. STRATTON, Director.

CIRCULAR OF THE BUREAU OF STANDARDS.

No. 129.

(Issued July, 27, 1922.)

UNITED STATES GOVERNMENT SPECIFICATION FOR  
ORDINARY LAUNDRY SOAP.

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION No. 32.

This Specification was officially adopted by the Federal Specifications Board on June 20, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of materials covered by it.

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1. GENERAL.

The soap desired under this specification is a well-made, uniformly mixed laundry or common soap, made from soda and fats, with no excessive proportion of rosin and a moderate amount of matter insoluble in alcohol, free from objectionable odor or makeweights, suitable for use with moderately hard water for general cleaning and laundry purposes. Bidder shall state size, weight, and number of cakes in each box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 36 per cent. Deliveries which yield more than 36 per cent volatile matter will be rejected without further test.

The sum of free alkali, total matter insoluble in alcohol, and sodium chloride shall be not less than 2 per cent nor more than 10 per cent.

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Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.5 per cent.

Matter insoluble in water shall not exceed 1.0 per cent.

Rosin shall not exceed 25 per cent.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constituents will be calculated on the basis of material containing 34 per cent of volatile matter.

The material will be purchased by net weight provided the matter volatile at 105° C. does not exceed 34 per cent. With deliveries containing more than 34 per cent, but not exceeding 36 per cent of matter volatile at 105° C., settlement will be made on the basis of 34 per cent of matter volatile at 105° C.; that is, sixty-six one-hundredths of a pound of nonvolatile matter shall be considered 1 pound of soap.

*Examples.*—1. Yield 33 per cent of matter volatile at 105° C.; pay for net weight.

2. Yield 35 per cent of matter volatile at 105° C.; percentage of net weight to be paid for is calculated as follows:

$$(100 - 35) \times 100/66 = 98.48 \text{ per cent.}$$

## 2. SAMPLING.

One cake shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 50 pounds each. In the case of smaller containers a cake shall be taken at random from each lot of containers totaling not to exceed 5,000 pounds. The total sample shall in all cases consist of not less than three cakes taken at random from separate containers. With very large lots, where the sample drawn as above will amount to more than 20 pounds, the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds.

Wrap the individual cakes tightly in paraffined paper at once and seal by rubbing the edges with a heated iron. The inspector should accurately weigh each wrapped cake, record its weight and the date of weighing on the wrapper, place the wrapped cakes in an air-tight container, which should be nearly filled, seal, mark, and send to the laboratory for test. Samples should be kept cool until tested. The seller shall have the option of being represented at the time of sampling and when he so requests shall be furnished with a duplicate sample.

### 3. LABORATORY EXAMINATION.

(a) **PREPARATION OF SAMPLE.**—In case of samples that can be easily disintegrated and mixed, run the entire sample through a suitable chopper, except where the sample is large, when each cake may be quartered and one-quarter of each cake run through the chopper. With samples that can not be handled as above, select a cake of average weight, quarter by cutting at right angles in the center, and shave equally from all freshly cut surfaces sufficient soap for analysis. Mix and weigh out all portions for analysis promptly. Preserve the remainder in an air-tight container in a cool place.

When a determination shows nonconformity with specification, a duplicate shall be run.

(b) **MATTER VOLATILE AT 105° C.**—Weigh 5 g of the sample in a porcelain or glass dish, about 6 to 7 cm in diameter and 4 cm deep, dry to constant weight in a vacuum oven or an inert atmosphere at a temperature not exceeding 105° C. (Time can be saved by having a layer of about 3 mm of ignited sand and a small stirring rod weighed with the dish and dissolving the sample in absolute alcohol, evaporating to dryness, breaking up the sample with the rod, adding more alcohol, again evaporating and completing the drying in the oven as above.) Report loss in weight as matter volatile at 105° C.

(c) **TOTAL MATTER INSOLUBLE IN ALCOHOL, FREE ALKALI, OR FREE ACID**—(1) *Matter Insoluble in Alcohol.*—Digest hot a 10 g sample with 200 cc of freshly boiled neutral ethyl alcohol (94 per cent or higher). Filter through a counterpoised filter paper neutral to phenolphthalein, or a weighed Gooch crucible with suction, protecting the solution during the operation from carbon dioxide and other acid fumes. Wash the residue on the paper or in the crucible with hot neutral alcohol until free from soap. Dry the filter paper or crucible and residue at 100 to 105° C. for three hours, cool, and weigh the total matter insoluble in alcohol.

(2) *Free Alkali or Free Acid.*—Titrate the filtrate from the above, using phenolphthalein as indicator, with standard acid or alkali solution, and calculate the alkalinity to sodium hydroxide (or potassium hydroxide) or acidity to oleic acid.

(3) *Matter Insoluble in Water.*—Proceed as in the determination of matter insoluble in alcohol. After filtering and thoroughly washing the residue extract it with water at 60° C. and wash the filter thoroughly. (When the matter insoluble in water is all inorganic, boiling water may be used for the extraction and

washing.) Dry the filter and residue at 100 to 105° C. for three hours, cool, and weigh matter insoluble in water. The nature of this may be determined by further examination.

(d) CHLORIDE.—Dissolve 5 g of the sample in 300 cc of water, boiling if necessary to effect solution of all soluble matter. Add an excess of neutral chlorine-free magnesium nitrate solution (about 25 cc of a 20 per cent  $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$  solution). Without cooling or filtering titrate with standard silver nitrate solution, using potassium chromate as indicator. Calculate the chloride as sodium chloride.

(e) ROSIN.—Wolff's Method<sup>1</sup>. Dissolve 5 g of the sample in 100 to 200 cc of hot water, add a slight excess of dilute sulphuric acid, heat until the fatty acids collect in a clear layer, cool to room temperature, extract with a small portion of ether, draw off water layer, and wash ether solution with water until free from mineral acid. Transfer to a 200 cc Erlenmeyer flask, evaporate off the ether and dry one hour at 105° C., cool, and dissolve in 20 cc of absolute alcohol. Then add 10 cc of a solution of one volume of concentrated sulphuric acid (specific gravity = 1.84) and four volumes of absolute alcohol, and boil for four minutes under a reflux condenser. Remove from steam bath and add to the liquid about five times its volume of 7 to 10 per cent sodium chloride solution and extract with ether. Shake out the aqueous portion two or three times with ether. Unite the ether solutions and wash with sodium chloride solution until the washings are neutral to methyl orange. Add 30 cc neutral alcohol and titrate the rosin acids with standard sodium hydroxide solution, using phenolphthalein as indicator. Calculate to rosin or rosin soap, as desired (1 cc normal alkali = 0.346 g rosin or 0.377 g rosin soda soap).

#### 4. REAGENTS.

(a) STANDARD SODIUM HYDROXIDE SOLUTION.—0.25 N, or about 10 g. sodium hydroxide dissolved in water and diluted to 1 liter. Standardized against Bureau of Standards benzoic acid.

(b) STANDARD SULPHURIC ACID SOLUTION.—0.5 N, or about 25.8 g strong sulphuric acid (specific gravity = 1.84) diluted to 1 liter. Standardized against standard sodium hydroxide solution, (a).

(c) STANDARD SILVER NITRATE SOLUTION.—0.10 N, or about 17 g silver nitrate dissolved in water and diluted to 1 liter. Standardized against chemically pure sodium chloride.

(d) POTASSIUM CHROMATE SOLUTION.—A 10 per cent solution of potassium chromate ( $\text{K}_2\text{CrO}_4$ ) in water.

<sup>1</sup> Chem.-Ztg., 38, pp. 369-70, 382-3, 430; Chem.-Abstr. 8, p. 2495 (1914).

DEPARTMENT OF COMMERCE.

U.S. BUREAU OF STANDARDS.  
George K. Burgess, Director.

CIRCULAR OF THE BUREAU OF STANDARDS, No. 129.

(Reprinted December 21, 1923.)

UNITED STATES GOVERNMENT SPECIFICATION FOR  
ORDINARY LAUNDRY SOAP.

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION No. 32.

This Specification was officially adopted by the Federal Specifications Board on July 3, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of ordinary laundry soap.

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1. GENERAL.

The soap desired under this specification is a well made, uniformly mixed laundry or common soap, made from soda and fats, with no excessive proportion of rosin and a moderate amount of matter insoluble in alcohol, free from objectionable odor or makeweights, suitable for use with moderately hard water for general cleaning and laundry purposes. Bidder shall state size, weight, and number of cakes in each box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 36 per cent. Deliveries which yield more than 36 per cent volatile matter will be rejected without further test.

The sum of free alkali, total matter insoluble in alcohol, and sodium chloride shall be not less than 2 per cent nor more than 10 per cent.

Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.5 per cent.

Matter insoluble in water shall not exceed 1.0 per cent.

Rosin shall not exceed 25 per cent.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constituents will be calculated on the basis of material containing 34 per cent of volatile matter.

The material will be purchased by net weight provided the matter volatile at 105° C. does not exceed 34 per cent. With deliveries containing more than 34 per cent, but not exceeding 36 per cent of matter volatile at 105° C., settlement will be made on the basis of 34 per cent of matter volatile at 105° C.; that is, sixty-six one-hundredths of a pound of nonvolatile matter shall be considered 1 pound of soap.

*Examples.*—1. Yield 33 per cent of matter volatile at 105° C.; pay for net weight.

2. Yield 35 per cent of matter volatile at 105° C.; percentage of net weight to be paid for is calculated as follows:

$$(100 - 35) \times 100/66 = 98.48 \text{ per cent.}$$

## 2. SAMPLING.

No samples shall be submitted with bid. One cake shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 50 pounds each. In the case of smaller containers a cake shall be taken at random from each lot of containers totaling not to exceed 5,000 pounds. The total sample shall in all cases consist of not less than three cakes taken at random from separate containers. With very large lots, where the sample drawn as above will amount to more than 20 pounds, the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds.

Wrap the individual cakes tightly in paraffined paper at once and seal by rubbing the edges with a heated iron. The inspector should accurately weigh each wrapped cake, record its weight

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*Specification for Ordinary Laundry Soap.*

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and the date of weighing on the wrapper, place the wrapped cakes in an air-tight container, which should be nearly filled, seal, mark, and send to the laboratory for test. Samples should be kept cool until tested. The seller shall have the option of being represented at the time of sampling and when he so requests shall be furnished with a duplicate sample.

**3. LABORATORY EXAMINATION.**

(a) **PREPARATION OF SAMPLE.**—In case of samples that can be easily disintegrated and mixed, run the entire sample through a suitable chopper, except where the sample is large, when each cake may be quartered and one-quarter of each cake run through the chopper. With samples that can not be handled as above, select a cake of average weight, quarter by cutting at right angles in the center, and shave equally from all freshly cut surfaces sufficient soap for analysis. Mix and weigh out all portions for analysis promptly. Preserve the remainder in an air-tight container in a cool place.

When a determination shows nonconformity with specification, a duplicate shall be run.

(b) **MATTER VOLATILE AT 105° C.**—Weigh 5 g of the sample in a porcelain or glass dish, about 6 to 7 cm in diameter and 4 cm deep, dry to constant weight in an inert atmosphere at a temperature not exceeding 105° C. (Time can be saved by having a layer of about 3 mm of ignited sand and a small stirring rod weighed with the dish and dissolving the sample in absolute alcohol, evaporating to dryness, breaking up the sample with the rod, adding more alcohol, again evaporating and completing the drying in the oven as above.) Report loss in weight as matter volatile at 105° C.

(c) **TOTAL MATTER INSOLUBLE IN ALCOHOL, FREE ALKALI, OR FREE ACID**—(1) *Matter Insoluble in Alcohol.*—Digest hot a 10 g sample with 200 cc of freshly boiled neutral ethyl alcohol (94 per cent or higher). Filter through a counterpoised filter paper neutral to phenolphthalein or a weighed Gooch crucible with suction, protecting the solution during the operation from carbon dioxide and other acid fumes. Wash the residue on the paper or in the crucible with hot neutral alcohol until free from soap. Dry the filter paper or crucible and residue at 100 to 105° C. for three hours, cool, and weigh the total matter insoluble in alcohol.

(2) *Free Alkali or Free Acid*.—Titrate the filtrate from the above, using phenolphthalein as indicator, with standard acid or alkali solution and calculate the alkalinity to sodium hydroxide (or potassium hydroxide) or acidity to oleic acid.

(3) *Matter Insoluble in Water*.—Proceed as in the determination of matter insoluble in alcohol. After filtering and thoroughly washing the residue extract it with water at 60° C. and wash the filter thoroughly. (When the matter insoluble in water is all inorganic, boiling water may be used for the extraction and washing.) Dry the filter and residue at 100 to 105° C. for three hours, cool, and weigh matter insoluble in water. The nature of this may be determined by further examination.

(d) *CHLORIDE*.—Dissolve 5 g of the sample in 300 cc of water, boiling if necessary to effect solution of all soluble matter. Add an excess of neutral chlorine-free magnesium nitrate solution (about 25 cc of a 20 per cent  $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$  solution). Without cooling or filtering titrate with standard silver nitrate solution, using potassium chromate as indicator. Calculate the chloride as sodium chloride.

(e) *ROSIN*.—*Wolff's Method*.<sup>1</sup>—Dissolve 5 g of the sample in 100 to 200 cc of hot water, add a slight excess of dilute sulphuric acid, heat until the fatty acids collect in a clear layer, cool to room temperature, extract with a small portion of ether, draw off water layer, and wash ether solution with water until free from mineral acid. Transfer to a 200 cc Erlenmeyer flask, evaporate off the ether and dry one hour at 105° C., cool, and dissolve in 20 cc of absolute alcohol. Then add 10 cc of a solution of one volume of concentrated sulphuric acid (specific gravity = 1.84) and four volumes of absolute alcohol and boil for four minutes under a reflux condenser. Remove from steam bath and add to the liquid about five times its volume of 7 to 10 per cent sodium chloride solution and extract with ether. Shake out the aqueous portion two or three times with ether. Unite the ether solutions and wash with sodium chloride solution until the washings are neutral to methyl orange. Add 30 cc neutral alcohol and titrate the rosin acids with standard sodium hydroxide solution, using phenolphthalein as indicator. Calculate to rosin or rosin soap, as desired (1 cc normal alkali = 0.346 g rosin or 0.377 g rosin soda soap).

<sup>1</sup>Chem. Ztg., 88, pp. 369-370, 382-383, 430; Chem.-Abstr. 8, p. 2495 (1914).

#### 4. REAGENTS.

(a) STANDARD SODIUM HYDROXIDE SOLUTION.—0.25 N, or about 10 g sodium hydroxide dissolved in water and diluted to 1 liter. Standardized against Bureau of Standards benzoic acid.

(b) STANDARD SULPHURIC ACID SOLUTION.—0.5 N, or about 25.8 g strong sulphuric acid (specific gravity = 1.84) diluted to 1 liter. Standardized against standard sodium hydroxide solution (a).

(c) STANDARD SILVER NITRATE SOLUTION.—0.10 N, or about 17 g silver nitrate dissolved in water and diluted to 1 liter. Standardized against chemically pure sodium chloride.

(d) POTASSIUM CHROMATE SOLUTION.—A 10 per cent solution of potassium chromate ( $K_2CrO_4$ ) in water.

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## DEPARTMENT OF COMMERCE.

U.S. BUREAU OF STANDARDS.

S. W. STRATTON, Director.

## CIRCULAR OF THE BUREAU OF STANDARDS.

No. 130.

(Issued July 27, 1922.)

UNITED STATES GOVERNMENT SPECIFICATION FOR  
GRIT CAKE SOAP.<sup>1</sup>

## FEDERAL SPECIFICATIONS BOARD.

## STANDARD SPECIFICATION No. 33.

This Specification was officially adopted by the Federal Specifications Board on June 20, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of materials covered by it.

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## 1. GENERAL.

(a) GRIT CAKE SOAP FOR FINE WORK SUCH AS GLASS AND ENAMEL.—The material desired under this specification is a compact cake soap containing about nine-tenths of its weight of clean, finely divided siliceous material which will not scratch glass or enameled surfaces, unscented, and of a light gray or white color. Cakes to be well compressed and of a satisfactory degree of friability, which must not be materially affected or lessened after immersion in or contact with water. Bidder shall state size, weight, and number of cakes to each box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 4 per cent. Deliveries which yield more than 4 per cent of volatile matter shall be rejected without further test.

<sup>1</sup> For specification for Scouring Compounds, see B. S. Circular No. 131. For specification for Hand Grit Soap, see B. S. Circular No. 132.

Alkali as alkaline salts (total alkalinity of matter insoluble in alcohol), calculated as sodium carbonate ( $\text{Na}_2\text{CO}_3$ ), shall not exceed 1 per cent.

Free alkali, calculated as sodium hydroxide ( $\text{NaOH}$ ), shall not exceed 0.1 per cent.

Insoluble siliceous material shall be not less than 88 per cent nor more than 93 per cent. This insoluble siliceous material must be mainly ground feldspar and all must pass a No. 100 screen, and at least 95 per cent must pass a No. 200 screen.

Rosin, sugar, and foreign matter shall not be present.

Anhydrous soda soap shall be within 1 per cent of the difference between 100 and the sum of the matter volatile at  $105^\circ\text{C}$ ., insoluble siliceous material, and alkali as alkaline salts.

Material will be purchased by net weight.

(b) **GRIT CAKE SOAP FOR SCOURING AND SCRUBBING.**—The material desired under this specification is a compact cake soap containing about four-fifths of its weight of clean, finely divided, siliceous material, unscented and of a light gray or white color. Cakes to be well compressed and of a satisfactory degree of friability, which must not be materially affected or lessened after immersion in or contact with water. Bidder shall state size, weight, and number of cakes to the box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at  $105^\circ\text{C}$ . shall not exceed 5 per cent. Deliveries which yield more than 5 per cent of volatile matter shall be rejected without further test.

Alkali as alkaline salts (total alkalinity of matter insoluble in alcohol), calculated as sodium carbonate ( $\text{Na}_2\text{CO}_3$ ), shall not exceed 3 per cent.

Free alkali, calculated as sodium hydroxide ( $\text{NaOH}$ ), shall not exceed 0.1 per cent.

Insoluble siliceous material shall be not less than 75 nor more than 85 per cent. This insoluble siliceous material should be mainly quartz. It all must pass a No. 100 screen.

Rosin, sugar, and foreign matter shall not be present.

Anhydrous soda soap shall be within 1 per cent of the difference between 100 and the sum of the matter volatile at  $105^\circ\text{C}$ ., insoluble siliceous material, and alkali as alkaline salts.

Material will be purchased by net weight.

## 2. SAMPLING.

One cake shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 50 pounds each. In the case of smaller containers a cake shall be taken at random from each lot of containers totaling not to exceed 5,000 pounds. The total sample shall in all cases consist of not less than three cakes taken at random from separate containers. With very large lots, where the sample drawn as above will amount to more than 20 pounds, the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds.

Wrap the individual cakes tightly in paraffined paper at once and seal by rubbing the edges with a heated iron. The inspector should accurately weigh each wrapped cake, record its weight and the date of weighing on the wrapper, place the wrapped cakes in an air-tight container, which should be nearly filled, seal, mark, and send to the laboratory for test. Samples should be kept cool until tested. The seller shall have the option of being represented at the time of sampling and when he so requests shall be furnished with a duplicate sample.

## 3. LABORATORY EXAMINATION.

(a) **PREPARATION OF SAMPLE.**—Select a cake of average weight, quarter by cutting at right angles in the center, and shave equally from all freshly cut surfaces sufficient soap for analysis. Mix and weigh out all portions for analysis promptly. Preserve the remainder in an air-tight container in a cool place. (With material that can not be quartered as above, break a cake of average weight and shave the sample from the freshly broken surfaces.)

When a determination shows nonconformity with specification, a duplicate shall be run.

(b) **MATTER VOLATILE AT 105° C.**—Weigh 5 g of the sample in a porcelain or glass dish, about 6 to 7 cm in diameter and 4 cm deep, dry to constant weight in a vacuum oven or an inert atmosphere at a temperature not exceeding 105° C. Report loss in weight as matter volatile at 105° C.

(c) **TOTAL MATTER INSOLUBLE IN ALCOHOL, FREE ALKALI, OR FREE ACID.**—(1) *Matter Insoluble in Alcohol.*—Digest hot a 5 g sample with 100 cc of freshly boiled neutral ethyl alcohol (94 per cent or higher). Filter through a counterpoised filter paper neutral to phenolphthalein, or a weighed Gooch crucible with suction into a dry weighed beaker, protecting the solution during the operation

from carbon dioxide and other acid fumes. Wash the residue on the paper or in the crucible with hot neutral alcohol until free from soap. Dry the filter paper or crucible and residue at 100 to 105° C for three hours, cool, and weigh the total matter insoluble in alcohol. (Since the percentage of the matter insoluble in alcohol is not required under this specification, time may be saved by omitting the drying and weighing and proceeding directly with the moist residue to the determination of matter insoluble in water (3).

(2) **FREE ALKALI OR FREE ACID.**—Titrate the filtrate from the above, using phenolphthalein as indicator, with standard acid or alkali solution, and calculate the alkalinity to sodium hydroxide (or potassium hydroxide) or acidity to oelic acid.

(3) **MATTER INSOLUBLE IN WATER.**—Proceed as in the determination of matter insoluble in alcohol. After filtering and thoroughly washing the residue, extract it with water at 60° C. and wash the filter thoroughly. (When the matter insoluble in water is all inorganic, boiling water may be used for the extraction and washing.) Dry the filter and residue at 100 to 105° C. for three hours, cool, and weigh matter insoluble in water. The nature of this may be determined by further examination. The insoluble matter should be siliceous. The approximate amount of feldspar contained in the abrasive material of scouring soap (when such material is known to contain nothing but feldspar or quartz or a mixture of the two) may be determined by decomposing about 0.5 g of the abrasive material with hydrofluoric acid, taking up the residue in water and hydrochloric acid and determining the  $\text{Al}_2\text{O}_3$ . This weight multiplied by 5.48 and divided by the weight of sample gives the approximate percentage of feldspar in the abrasive material. Feldspar may be identified and the relative amounts of feldspar and quartz roughly determined by means of the petrographic microscope.

(4) **ALKALI AS ALKALINE SALTS (TOTAL AKLALINITY OF MATTER INSOLUBLE IN ALCOHOL).**—Titrate the filtrate from the determination of matter insoluble in water with standard acid, using methyl orange as indicator. Calculate alkalinity to sodium carbonate ( $\text{Na}_2\text{CO}_3$ ).

(d) **SCREEN TEST.**—Transfer a weighed sample of the insoluble siliceous material to a No. 100 screen and carefully brush through. Weigh the amount passing through and calculate percentage. After weighing transfer to a No. 200 screen and treat in the same manner. Weigh the amount passing through and calculate percentage.

(e) TOTAL ANHYDROUS SOAP.—Evaporate the alcoholic solution obtained after filtering off and washing the matter insoluble in alcohol—(c), (1) and (2)—to dryness, dry at  $105^{\circ}$  C. to constant weight. Report the result as total anhydrous soap.

(f) ROSIN.—A qualitative test for rosin may be made as follows: After decomposing a solution of the soap and separating the fatty acids heat a small quantity of the latter with acetic anhydride, cool, place a few drops on a spot plate, and add a drop of  $H_2SO_4$  (specific gravity = 1.53) to this. A fugitive violet color indicates the presence of rosin.

(g) SUGAR.—A qualitative test for sugar may be made as follows: Add a decided excess of hydrochloric acid to a solution of the soap, heat on a steam bath for 15 minutes, cool, filter from fatty acids, and test a portion of the filtrate which has been neutralized with sodium hydroxide solution by boiling for two minutes with an equal volume of boiling Fehling solution. The formation of red cuprous oxide indicates the presence of sugar.

#### 4. REAGENTS.

(a) STANDARD SODIUM HYDROXIDE SOLUTION.—0.25 N, or about 10 g sodium hydroxide dissolved in water and diluted to 1 liter. Standardized against Bureau of Standards benzoic acid.

(b) STANDARD SULPHURIC ACID SOLUTION.—0.5 N, or about 25.8 g strong sulphuric acid (specific gravity = 1.84) diluted to 1 liter. Standardized against standard sodium hydroxide solution (a).

(c) SULPHURIC ACID (SPECIFIC GRAVITY = 1.53).—Mix 62.5 cc of strong sulphuric acid (specific gravity = 1.84) with 61.5 cc of water.

(d) FEHLING SOLUTION.—(1) *Copper Sulphate Solution*.—Dissolve 34.639 g of copper sulphate ( $CuSO_4 \cdot 5H_2O$ ) in water and dilute to 500 cc.

(2) *Alkaline Tartrate Solution*.—Dissolve 173 g of Rochelle salts ( $NaKC_4H_4O_6 \cdot 4H_2O$ ) and 50 g of sodium hydroxide in water and dilute to 500 cc. Mix equal volumes of (1) and (2) immediately before use

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No. 33a**

**DEPARTMENT OF COMMERCE**

**U. S. BUREAU OF STANDARDS**  
**George K. Burgess, Director**

**CIRCULAR OF THE BUREAU OF STANDARDS, No. 130**

[2d ed. Issued November 23, 1926]

**UNITED STATES GOVERNMENT MASTER SPECIFICATION FOR  
SOAP, CAKE, GRIT**

**FEDERAL SPECIFICATIONS BOARD SPECIFICATION No. 33a**

[Revised October 28, 1926]

This specification was officially promulgated by the Federal Specifications Board on July 3, 1922, for the use of the departments and independent establishments of the Government in the purchase of grit cake soap.

[The latest date on which the technical requirements of this revision shall become mandatory for all departments and independent establishments of the Government is January 28, 1927. They may be put into effect, however, at any earlier date after promulgation]

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**I. GENERAL SPECIFICATIONS**

There are no general specifications applicable to this specification.

**II. TYPES**

Grit cake soap shall be furnished in two types, as follows: Type A, for fine work, such as glass and enamel; type B, for scouring and scrubbing.

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### III. MATERIAL AND WORKMANSHIP

Grit cake soap shall be satisfactory for the purpose intended.

### IV. GENERAL REQUIREMENTS

See Detail requirements.

### V. DETAIL REQUIREMENTS

Failure to meet any of the following requirements will be cause for rejection.

#### 1. TYPE A

Matter volatile at 105 to 110° C. shall not exceed 4 per cent. Deliveries which yield more than 4 per cent of volatile matter shall be rejected without further test.

Alkali as alkaline salts (total alkalinity of matter insoluble in alcohol), calculated as sodium carbonate ( $\text{Na}_2\text{CO}_3$ ), shall not exceed 1 per cent.

Free alkali, calculated as sodium hydroxide ( $\text{NaOH}$ ), shall not exceed 0.1 per cent.

Insoluble siliceous material shall be not less than 88 per cent nor more than 93 per cent.

The insoluble siliceous material shall consist of not less than 90 per cent of ground feldspar. All of the insoluble siliceous material shall pass through a No. 100 sieve, and the residue retained on a No. 200 sieve shall not exceed 5 per cent.

Rosin, sugar, and foreign matter shall not be present.

Anhydrous soda soap shall be within 1 per cent of the difference between 100 and the sum of the matter volatile at 105 to 110° C., insoluble siliceous material, and alkali as alkaline salts.

The cakes shall be well compressed and of a satisfactory degree of friability, which shall not be materially affected or lessened after immersion in or contact with water.

The material shall not scratch glass or enameled surfaces.

The material shall be unscented and shall be of a light gray or white color.

#### 2. TYPE B

Matter volatile at 105 to 110° C. shall not exceed 5 per cent. Deliveries which yield more than 5 per cent of volatile matter shall be rejected without further test.

Alkali as alkaline salts (total alkalinity of matter insoluble in alcohol), calculated as sodium carbonate ( $\text{Na}_2\text{CO}_3$ ), shall not exceed 3 per cent.

Free alkali, calculated as sodium hydroxide ( $\text{NaOH}$ ), shall not exceed 0.1 per cent.

Insoluble siliceous material shall not be less than 75 nor more than 85 per cent.

The insoluble siliceous material shall be mainly quartz, and it all must pass through a No. 100 sieve.

Rosin, sugar, and foreign matter shall not be present.

Anhydrous soda soap shall be within 1 per cent of the difference between 100 and the sum of the matter volatile at 105 to 110° C., insoluble siliceous material, and alkali as alkaline salts.

The cakes shall be well compressed and of a satisfactory degree of friability, which shall not be materially affected or lessened after immersion in or contact with water.

The material shall be unscented and shall be of a light gray or white color.

## VI. METHODS OF INSPECTION, TESTS, AND BASIS OF PURCHASE

### 1. SAMPLING

(a) No samples shall be submitted with bids.

(b) One cake shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 50 pounds each. In the case of smaller containers, a cake shall be taken at random from each lot of containers totaling not to exceed 5,000 pounds. The total sample shall in all cases consist of not less than three cakes taken at random from separate containers. With very large lots, where the sample drawn as above will amount to more than 20 pounds, the percentage of packages sampled shall be reduced so that the amount drawn shall not exceed 20 pounds.

The inspector shall note whether the material meets the specification regarding compression and friability.

Wrap the individual cakes tightly in paraffined paper at once and seal by rubbing the edges with a heated iron. The inspector should accurately weigh each wrapped cake, record its weight and the date of weighing on the wrapper, place the wrapped cakes in an air-tight container, which should be nearly filled, seal, mark, and send to the laboratory for test. Samples should be kept cool until tested. The seller shall have the option of being represented at the time of sampling, and, when he so requests, shall be furnished with a duplicate sample.

### 2. METHODS OF TESTING

(a) **PRELIMINARY TESTS.**—Note the net weight, color, and odor of the cakes; also note whether the cakes are well compressed and the

friability before and after immersion in or contact with water. With type A, only, determine whether the material scratches glass or enameled surfaces, rubbing the material onto a moistened cloth and then rubbing the surface with the cloth, keeping the soap in contact with the glass or enamel.

(b) **PREPARATION OF SAMPLE.**—Break a cake of average weight and shave from the freshly broken surfaces sufficient soap for analysis. Mix and weigh out all portions for analysis promptly. Preserve the remainder in an air-tight container in a cool place.

When a determination shows nonconformity with specification, a duplicate shall be run.

(c) **MATTER VOLATILE AT 105° C.**—Weigh 5 g of the sample in a porcelain or glass dish, about 6 to 7 cm in diameter and 4 cm deep, dry to constant weight in an inert atmosphere at a temperature not exceeding 105 to 110° C. Report loss in weight as matter volatile at 105° C.

(d) **FREE ALKALI OR FREE ACID.**—Digest hot a 5 g sample with 100 cc of freshly boiled neutral ethyl alcohol (94 per cent or higher). Filter through a counterpoised filter paper neutral to phenolphthalein or a weighed Gooch crucible with suction into a dry weighed beaker, protecting the solution during the operation from carbon dioxide and other acid fumes. Wash the residue on the paper or in the crucible with hot neutral alcohol until free from soap. Titrate the filtrate, using phenolphthalein as indicator, with standard acid or alkali solution, and calculate the alkalinity to sodium hydroxide or acidity to oleic acid.

(e) **MATTER INSOLUBLE IN WATER.**—After filtering and thoroughly washing the residue from (d), extract and wash it thoroughly with hot water. Dry the filter and residue at 105 to 110° C. for three hours, cool, and weigh matter insoluble in water. The nature of this may be determined by further examination. The insoluble matter should be siliceous. The approximate amount of feldspar contained in the abrasive material of scouring soap (when such material is known to contain nothing but feldspar or quartz or a mixture of the two) may be determined by decomposing about 0.5 g of the abrasive material with hydrofluoric acid, taking up the residue in water and hydrochloric acid and determining the  $Al_2O_3$ . This weight multiplied by 5.48 and divided by the weight of sample gives the approximate percentage of feldspar in the abrasive material. Feldspar may be identified and the relative amounts of feldspar and quartz roughly determined by means of the petrographic microscope.

(f) **ALKALI AS ALKALINE SALTS (TOTAL ALKALINITY OF MATTER INSOLUBLE IN ALCOHOL).**—Titrate the filtrate from the determination of matter insoluble in water with standard acid, using methyl orange as indicator. Calculate alkalinity to sodium carbonate ( $Na_2CO_3$ ).

(g) **SIEVE TEST.**—Dry in an oven at 105 to 110° C. a No. 100 sieve and a No. 200 sieve, cool, and weigh accurately. Weigh an amount of soap containing 10 g of insoluble siliceous material (see VI, 2, (e)), transfer to a beaker, add about 200 cc of water, and digest on a steam bath about one hour to dissolve the soap and other soluble matter. Pour the solution through the No. 100 sieve, wash the insoluble material from the beaker onto the sieve with water, and wash with water until all but the particles too coarse to pass the No. 100 sieve have been washed through, catching all of the liquid and solid matter passing through the sieve in a clean beaker or dish. Dry the sieve for one hour at 105 to 110° C., cool, and weigh. Calculate the percentage of residue retained on the No. 100 sieve, based on the insoluble siliceous material. (If the material forms lumps or aggregates on washing with water, a camel's-hair brush may be used on the sieve.)

In a similar manner transfer the material that has passed through the No. 100 sieve to the No. 200 sieve and wash with water until all but the particles too coarse to pass the No. 200 sieve have been washed through. Dry the sieve for one hour at 105 to 110° C., cool, and weigh. Add the weight of the residue retained on the No. 100 sieve to the weight of the residue found on the No. 200 sieve and calculate the sum to percentage of residue retained on the No. 200 sieve, based on the insoluble siliceous material.

(h) **TOTAL ANHYDROUS SOAP.**—Evaporate the alcoholic solution obtained after filtering off and washing the matter insoluble in alcohol (VI, 2 (d)) to dryness, dry at 105 to 110° C. to constant weight. Report the result as total anhydrous soap.

(i) **ROSIN.**—A qualitative test for rosin may be made as follows: After decomposing a solution of the soap and separating the fatty acids, heat a small quantity of the latter with acetic anhydride, cool, place a few drops on a spot plate, and add a drop of  $\text{H}_2\text{SO}_4$  (specific gravity=1.53) to this. A fugitive violet color indicates the presence of rosin.

(j) **SUGAR.**—A qualitative test for sugar may be made as follows: Add a decided excess of hydrochloric acid to a solution of the soap, heat on a steam bath for 15 minutes, cool, filter from fatty acids, and test a portion of the filtrate which has been neutralized with sodium hydroxide solution by boiling for two minutes with an equal volume of boiling Fehling solution. The formation of red cuprous oxide indicates the presence of sugar.

### 3. REAGENTS

(a) **STANDARD SODIUM HYDROXIDE SOLUTION.**—0.25 *N*, or about 10 g, sodium hydroxide dissolved in water and diluted to 1 liter. Standardize against Bureau of Standards benzoic acid.

(b) STANDARD SULPHURIC ACID SOLUTION.—0.5 *N*, or about 25.8 g, strong sulphuric acid (specific gravity=1.84) diluted to 1 liter. Standardize against standard sodium hydroxide solution VI, 3 (a).

(c) SULPHURIC ACID (SPECIFIC GRAVITY=1.53).—Mix 62.5 cc of strong sulphuric acid (specific gravity=1.84) with 61.5 cc of water.

(d) FEHLING SOLUTION.—(1) *Copper Sulphate Solution*.—Dissolve 34.639 g of copper sulphate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) in water and dilute to 500 cc.

(2) *Alkaline Tartrate Solution*.—Dissolve 173 g of Rochelle salts ( $\text{NaKC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$ ) and 50 g of sodium hydroxide in water and dilute to 500 cc. Mix equal volumes of (1) and (2) immediately before use.

(e) METHYL ORANGE INDICATOR.—Dissolve 1 g of methyl orange in 1 liter of distilled water

(f) PHENOLPHTHALEIN INDICATOR.—Dissolve 1 g of pure phenolphthalein in 100 cc of 85 to 95 per cent ethyl alcohol.

#### 4. BASIS OF PURCHASE

Material under each type shall be purchased by net weight.

### VII. PACKING AND MARKING

Packing and marking shall be in accordance with commercial practice, unless otherwise specified.

### VIII. NOTES

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DEPARTMENT OF COMMERCE.

U. S. BUREAU OF STANDARDS.

George K. Burgess, Director.

CIRCULAR OF THE BUREAU OF STANDARDS, No. 131.

(Reprinted December 21, 1923.)

UNITED STATES GOVERNMENT SPECIFICATION FOR  
SCOURING COMPOUNDS FOR FLOORS, (a) AND (b),  
AND SOAP SCOURING COMPOUND, (c).<sup>1</sup>

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION NO. 34.

This Specification was officially adopted by the Federal Specifications Board on July 3, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of scouring compounds for floors, (a) and (b), and soap scouring compound (c).

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1. GENERAL.

(a) SCOURING COMPOUND FOR FINE MARBLE FLOORS.—The material desired under this specification is a uniform powder containing about nine-tenths of its weight of clean, finely divided, siliceous material, the remainder being sodium carbonate or soap, or both. It must not scratch nor discolor the surfaces on which it is to be used; to be unscented and of a light gray or white color. Bidder shall state size and weight of package.

<sup>1</sup> For Specification for Grit Cake Soap see B. S. Circular No. 130; for Specification for Hand Grit Soap see B. S. Circular No. 132.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 10 per cent.

The sum of sodium carbonate and anhydrous soap shall not exceed 7 per cent nor be less than 2 per cent.

Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.1 per cent.

Insoluble siliceous material shall be not less than 85 per cent nor more than 95 per cent. It all must pass a No. 100 sieve, and at least 95 per cent must pass a No. 200 sieve. It must not scratch marble.

Material will be purchased by net weight.

(b) SCOURING COMPOUND FOR TILE OR CERAMIC AND TERRAZZO FLOORS.—The material desired under this specification is a uniform powder containing about nine-tenths of its weight of clean, finely divided, siliceous material, the remainder being sodium carbonate or soap, or both; to be unscented and of a light gray or white color. Bidder shall state size and weight of package.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 10 per cent.

The sum of sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) and anhydrous soap shall not exceed 10 per cent nor be less than 2 per cent.

Insoluble siliceous material shall be not less than 85 per cent nor more than 95 per cent. Ninety per cent must pass a No. 80 sieve, and at least 99 per cent must pass a No. 60 sieve.

Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.1 per cent.

Material will be purchased by net weight.

(c) SOAP SCOURING COMPOUND.—The material desired under this specification is a mixture of finely powdered, light colored siliceous material, sodium carbonate, and powdered soap. It must be free from caustic alkali and be unscented. Bidder shall state size and weight of package.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 10 per cent.

Carbonated alkali, calculated as sodium carbonate ( $\text{Na}_2\text{CO}_3$ ), shall be not less than 15 per cent nor more than 20 per cent.

Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.1 per cent.

Anhydrous soap shall be not less than 5 per cent nor more than 10 per cent.

Insoluble siliceous material shall be not less than 60 per cent nor more than 80 per cent. Ninety per cent must pass a No. 80 sieve, and at least 99 per cent shall pass a No. 60 sieve.

## 2. SAMPLING.

(a) No samples shall be submitted with bids.

(b) **WHEN PACKED IN CANS OR CARTONS.**—One can or carton shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 50 pounds each. In the case of smaller containers a can or carton shall be taken at random from each lot of containers totaling not to exceed 5,000 pounds. The total sample shall in all cases consist of not less than three cans or cartons taken at random from separate containers. With very large lots, where the sample drawn as above will amount to more than 20 pounds, the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds. Wrap the individual cans or cartons tightly in paraffined paper at once and seal by rubbing the edges with a heated iron. The inspector should accurately weigh each wrapped can or carton, record its weight and the date of weighing on the wrapper, place the wrapped cans or cartons in an air-tight container, which should be nearly filled, seal, mark, and send to the laboratory for test. Samples should be kept cool until tested. The seller shall have the option of being represented at the time of sampling and when he so requests shall be furnished with a duplicate sample.

(c) **WHEN IN BULK.**—A grab sample of not less than one-half pound shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 100 pounds each. In case of smaller containers a grab sample of not less than one-half pound shall be taken at random from each lot of containers totaling not to exceed 10,000 pounds. The total sample shall in all cases consist of not less than three grab portions taken at random from separate containers. With very large lots, where the sample drawn as above will amount to more than 20 pounds, the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds. The inspector should rapidly mix the sample, place in an air-tight container, which shall be filled; seal, mark, accurately weigh, record its weight and date of weighing on the package, and send to the laboratory for test. Samples should be kept cool until

tested. The seller shall have the option of being represented at the time of sampling and when he so requests shall be furnished with a duplicate sample.

### 3. LABORATORY EXAMINATION.

(a) **PREPARATION OF SAMPLE.**—Rapidly disintegrate and mix the sample, if desired, quarter down to about 1 pound, and weigh out all portions for analysis at once. Unused portions of the sample used for analysis shall be preserved in an air-tight container in a cool place.

When a determination shows nonconformity with specification, a duplicate shall be run.

(b) **MATTER VOLATILE AT 105° C.**—Weigh 5 g of the sample in a porcelain or glass dish, about 6 to 7 cm in diameter and 4 cm deep, dry to constant weight in an inert atmosphere at a temperature not exceeding 105° C. Report loss in weight as matter volatile at 105° C.

(c) **TOTAL MATTER INSOLUBLE IN ALCOHOL, FREE ALKALI, OR FREE ACID.**—(1) *Matter Insoluble in Alcohol.*—Digest hot a 5 g sample with 100 cc of freshly boiled neutral ethyl alcohol (94 per cent or higher). Filter through a counterpoised filter paper neutral to phenolphthalein, or a weighed Gooch crucible with suction into a dry weighed beaker, protecting the solution during the operation from carbon dioxide and other acid fumes. Wash the residue on the paper or in the crucible with hot neutral alcohol until free from soap. Dry the filter paper or crucible and residue at 100 to 105° C. for three hours, cool, and weigh the total matter insoluble in alcohol. (Since the percentage of the matter insoluble in alcohol is not required under this specification, time may be saved by omitting the drying and weighing and proceeding directly with the moist residue to the determination of matter insoluble in water (3).

(2) *Free Alkali or Free Acid.*—Titrate the filtrate from the above, using phenolphthalein as indicator, with standard acid or alkali solution and calculate the alkalinity to sodium hydroxide (or potassium hydroxide) or acidity to oleic acid.

(3) *Matter Insoluble in Water.*—Proceed as in the determination of matter insoluble in alcohol. After filtering and thoroughly washing the residue extract it with water at 60° C. and wash the filter thoroughly. (When the matter insoluble in water is all inorganic, boiling water may be used for the extraction and washing.) Dry the filter and residue at 100 to 105° C. for three hours, cool, and weigh matter insoluble in water. The nature of this

may be determined by further examination. The insoluble matter should be siliceous.

(4) *Alkali as Alkaline Salts (Total Alkalinity of Matter Insoluble in Alcohol).*—Titrate the filtrate from the determination of matter insoluble in water with standard acid, using methyl orange as indicator. Calculate alkalinity to sodium carbonate ( $\text{Na}_2\text{CO}_3$ ).

(d) *SIEVE TEST.*—Transfer a weighed sample of the insoluble siliceous material to a No. 100 or No. 60 sieve and carefully brush through. Weigh the amount passing through and calculate percentage. After weighing transfer to a No. 200 or No. 80 sieve and treat in the same manner. Weigh the amount passing through and calculate percentage.

(e) *TOTAL ANHYDROUS SOAP.*—Evaporate the alcoholic solution obtained after filtering off and washing the matter insoluble in alcohol—(c), (1) and (2)—to dryness, dry at  $105^\circ\text{C}$ . to constant weight. Report the result as total anhydrous soap.

#### 4. REAGENTS.

(a) *STANDARD SODIUM HYDROXIDE SOLUTION.*—0.25 N, or about 10 g sodium hydroxide dissolved in water and diluted to 1 liter. Standardized against Bureau of Standards benzoic acid.

(b) *STANDARD SULPHURIC ACID SOLUTION.*—0.5 N, or about 25.8 g strong sulphuric acid (specific gravity = 1.84) diluted to 1 liter. Standardized against standard sodium hydroxide solution (a).

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U. S. DEPARTMENT OF COMMERCE.  
U. S. BUREAU OF STANDARDS.  
S. W. STRATTON, Director.

CIRCULAR OF THE BUREAU OF STANDARDS.

No. 132.

(Issued July 27, 1922.)

UNITED STATES GOVERNMENT SPECIFICATION FOR  
HAND GRIT SOAP.<sup>1</sup>

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION No. 35.

This Specification was officially adopted by the Federal Specifications Board on June 20, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of materials covered by it.

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1. GENERAL.

The material desired under this specification is a high-grade cake soap containing about one-third its weight of clean, finely divided insoluble siliceous matter, as free as possible from water, either uncolored or colored in a manner indicated in the contract, either unscented or perfumed in a manner indicated in the contract for the same, thoroughly saponified, and well compressed in firm, smooth cakes.

Bidder shall state size, weight, and number of cakes in each box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 25 per cent. Deliveries which yield more than 25 per cent of volatile matter will be rejected without further test.

<sup>1</sup> For Specification for Grit Cake Soap see B. S. Circular No. 130; For Specification for Scouring Compounds see B. S. Circular No. 131.

Alkali as alkaline salts (total alkalinity of matter insoluble in alcohol), calculated as sodium carbonate ( $\text{Na}_2\text{CO}_3$ ), shall not exceed 1 per cent.

Free alkali, calculated as sodium hydroxide ( $\text{NaOH}$ ), shall not exceed 0.1 per cent.

Insoluble siliceous material shall be not less than 25 nor more than 40 per cent. This siliceous material must be so finely ground that not less than 98 per cent of it will pass through a No. 100 screen and not less than 90 per cent through a No. 200 screen.

Rosin, sugar, and foreign matter shall not be present.

Anhydrous soda soap shall be within 1 per cent of the difference between 100 and the sum of matter volatile at  $105^\circ \text{C}$ ., insoluble siliceous material, and alkali as alkaline salts.

The percentage of matter volatile at  $105^\circ \text{C}$ . will be computed on the basis of the soap as received, but all other constituents will be calculated to the basis of material containing 25 per cent of matter volatile at  $105^\circ \text{C}$ .

Material will be purchased by net weight.

## 2. SAMPLING.

One cake shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 50 pounds each. In the case of smaller containers a cake shall be taken at random from each lot of containers totaling not to exceed 5,000 pounds. The total sample shall in all cases consist of not less than three cakes taken at random from separate containers. With very large lots, where the sample drawn as above will amount to more than 20 pounds, the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds. Wrap the individual cakes tightly in paraffined paper at once and seal by rubbing the edges with a heated iron. The inspector should accurately weigh each wrapped cake, record its weight and the date of weighing on the wrapper, place the wrapped cakes in an air-tight container, which should be nearly filled, seal, mark, and send to the laboratory for test. Samples should be kept cool until tested. The seller shall have the option of being represented at the time of sampling and when he so requests shall be furnished with a duplicate sample.

## 3. LABORATORY EXAMINATION.

(a) PREPARATION OF SAMPLE.—Select a cake of average weight, quarter by cutting at right angles in the center, and shave equally from all freshly cut surfaces sufficient soap for analysis. Mix

and weigh out all portions for analysis promptly. Preserve the remainder in an air-tight container in a cool place. (With material that can not be quartered as above, break a cake of average weight and shave the sample from the freshly broken surfaces.)

When a determination shows nonconformity with specification, a duplicate shall be run.

(b) **MATTER VOLATILE AT 105° C.**—Weigh 5 g of the sample in a porcelain or glass dish, about 6 to 7 cm in diameter and 4 cm deep, dry to constant weight in a vacuum oven or an inert atmosphere at a temperature not exceeding 105° C. Report loss in weight as matter volatile at 105° C.

(c) **TOTAL MATTER INSOLUBLE IN ALCOHOL, FREE ALKALI, OR FREE ACID.**—(1) *Matter Insoluble in Alcohol.*—Digest hot a 5 g sample with 100 cc of freshly-boiled neutral ethyl alcohol (94 per cent or higher). Filter through a counterpoised filter paper neutral to phenolphthalein, or a weighed Gooch crucible with suction into a dry weighed beaker, protecting the solution during the operation from carbon dioxide and other acid fumes. Wash the residue on the paper or in the crucible with hot neutral alcohol until free from soap. Dry the filter paper or crucible and residue at 100 to 105° C. for three hours, cool, and weigh the total matter insoluble in alcohol. (Since the percentage of the matter insoluble in alcohol is not required under this specification, time may be saved by omitting the drying and weighing and proceeding directly with the moist residue to the determination of matter insoluble in water (3).)

(2) *Free Alkali or Free Acid.*—Titrate the filtrate from the above, using phenolphthalein as indicator, with standard acid or alkali solution and calculate the alkalinity to sodium hydroxide (or potassium hydroxide) or acidity to oleic acid.

(3) *Matter Insoluble in Water.*—Proceed as in the determination of matter insoluble in alcohol. After filtering and thoroughly washing the residue extract it with water at 60° C. and wash the filter thoroughly. (When the matter insoluble in water is all inorganic, boiling water may be used for the extraction and washing.) Dry the filter and residue at 100 to 105° C. for three hours, cool, and weigh matter insoluble in water. The nature of this may be determined by further examination. The insoluble matter should be siliceous.

(4) *Alkali as Alkaline Salts (Total Alkalinity of Matter Insoluble in Alcohol).*—Titrate the filtrate from the determination of matter

insoluble in water with standard acid, using methyl orange as indicator. Calculate alkalinity to sodium carbonate ( $\text{Na}_2\text{CO}_3$ ).

(d) SCREEN TEST.—Transfer a weighed sample of the insoluble siliceous material to a No. 100 screen and carefully brush through. Weigh the amount passing through and calculate percentage. After weighing transfer to a No. 200 screen and treat in the same manner, weigh the amount passing through, and calculate percentage.

(e) TOTAL ANHYDROUS SOAP.—Evaporate the alcoholic solution obtained after filtering off and washing the matter insoluble in alcohol—(c), (1) and (2)—to dryness, dry at  $105^\circ\text{C}$ . to constant weight. Report the result as total anhydrous soap.

(f) ROSIN.—A qualitative test for rosin may be made as follows: After decomposing a solution of the soap and separating the fatty acids heat a small quantity of the latter with acetic anhydride, cool, place a few drops on a spot plate, and add a drop of  $\text{H}_2\text{SO}_4$  (specific gravity = 1.53) to this. A fugitive violet color indicates the presence of rosin.

(g) SUGAR.—A qualitative test for sugar may be made as follows: Add a decided excess of hydrochloric acid to a solution of the soap, heat on a steam bath for 15 minutes, cool, filter from fatty acids, and test a portion of the filtrate which has been neutralized with sodium hydroxide solution by boiling for 2 minutes with an equal volume of boiling Fehling solution. The formation of red cuprous oxide indicates the presence of sugar.

#### 4. REAGENTS.

(a) STANDARD SODIUM HYDROXIDE SOLUTION.—0.25 N, or about 10 g sodium hydroxide dissolved in water and diluted to 1 liter. Standardized against Bureau of Standards benzoic acid.

(b) STANDARD SULPHURIC ACID SOLUTION.—0.5 N, or about 25.8 g strong sulphuric acid (specific gravity = 1.84) diluted to 1 liter. Standardized against standard sodium hydroxide solution (a).

(c) SULPHURIC ACID (SPECIFIC GRAVITY = 1.53).—Mix 62.5 cc of sulphuric acid (specific gravity = 1.84) with 61.5 cc of water.

(d) FEHLING SOLUTION.—(1) *Copper Sulphate Solution*.—Dissolve 34.639 g of copper sulphate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) in water and dilute to 500 cc.

(2) *Alkaline Tartrate Solution*.—Dissolve 173 g. of Rochelle salts ( $\text{NaKC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$ ) and 50 g of sodium hydroxide in water and dilute to 500 cc. Mix equal volumes of (1) and (2) immediately before use.

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U. S. Gov't.  
Standard  
Specification,  
No. 35.

DEPARTMENT OF COMMERCE.  
U. S. BUREAU OF STANDARDS.  
George K. Burgess, Director.

CIRCULAR OF THE BUREAU OF STANDARDS, NO. 132.

[2d ed. Feb. 1, 1924.]

UNITED STATES GOVERNMENT SPECIFICATION FOR  
HAND GRIT SOAP.<sup>1</sup>

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION NO. 35.

This Specification was officially adopted by the Federal Specifications Board on July 3, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of hand grit soap.

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1. GENERAL.

The material desired under this specification is a high-grade cake soap containing about one-third its weight of clean, finely divided insoluble siliceous matter, as free as possible from water, either uncolored or colored in a manner indicated in the contract, either unscented or perfumed in a manner indicated in the contract for the same, thoroughly saponified, and well compressed in firm, smooth cakes.

Bidder shall state size, weight, and number of cakes in each box.

Failure to meet any of the following requirements will be cause for rejection:

Matter volatile at 105° C. shall not exceed 25 per cent. Deliveries which yield more than 25 per cent of volatile matter will be rejected without further test.

Alkali as alkaline salts (total alkalinity of matter insoluble in alcohol), calculated as sodium carbonate ( $\text{Na}_2\text{CO}_3$ ), shall not exceed 1 per cent.

<sup>1</sup> For Specification for Grit Cake Soap see B. S. Circular No. 130; for Specification for Scouring Compounds see B. S. Circular No. 131.

Free alkali, calculated as sodium hydroxide (NaOH), shall not exceed 0.1 per cent.

Insoluble siliceous material shall be not less than 25 nor more than 40 per cent. This siliceous material must be so finely ground that not less than 98 per cent of it will pass through a No. 100 sieve and not less than 90 per cent through a No. 200 sieve.

Rosin, sugar, and foreign matter shall not be present.

Anhydrous soda soap shall be within 1 per cent of the difference between 100 and the sum of matter volatile at 105° C., insoluble siliceous material, and alkali as alkaline salts.

The percentage of matter volatile at 105° C. will be computed on the basis of the soap as received, but all other constituents will be calculated to the basis of material containing 25 per cent of matter volatile at 105° C.

Material will be purchased by net weight.

## 2. SAMPLING.

No samples shall be submitted with bids. One cake shall be taken at random from not less than 1 per cent of the vendors' shipping containers, provided such containers contain not less than 50 pounds each. In the case of smaller containers a cake shall be taken at random from each lot of containers totaling not to exceed 5,000 pounds. The total sample shall in all cases consist of not less than three cakes taken at random from separate containers. With very large lots, where the sample drawn as above will amount to more than 20 pounds, the percentage of packages sampled shall be reduced, so that the amount drawn shall not exceed 20 pounds. Wrap the individual cakes tightly in paraffined paper at once and seal by rubbing the edges with a heated iron. The inspector should accurately weigh each wrapped cake, record its weight and the date of weighing on the wrapper, place the wrapped cakes in an air-tight container, which should be nearly filled, seal, mark, and send to the laboratory for test. Samples should be kept cool until tested. The seller shall have the option of being represented at the time of sampling and when he so requests shall be furnished with a duplicate sample.

## 3. LABORATORY EXAMINATION.

(a) PREPARATION OF SAMPLE.—Select a cake of average weight, quarter by cutting at right angles in the center, and shave equally from all freshly cut surfaces sufficient soap for analysis. Mix and weigh out all portions for analysis promptly. Preserve the remainder in an air-tight container in a cool place. (With material

that can not be quartered as above, break a cake of average weight and shave the sample from the freshly broken surfaces.)

When a determination shows nonconformity with specification, a duplicate shall be run.

(b) **MATTER VOLATILE AT 105° C.**—Weigh 5 g of the sample in a porcelain or glass dish, about 6 to 7 cm in diameter and 4 cm deep, dry to constant weight in an inert atmosphere at a temperature not exceeding 105° C. Report loss in weight as matter volatile at 105° C.

(c) **TOTAL MATTER INSOLUBLE IN ALCOHOL, FREE ALKALI, OR FREE ACID.**—(1) *Matter Insoluble in Alcohol.*—Digest hot a 5 g sample with 100 cc of freshly-boiled neutral ethyl alcohol (94 per cent or higher). Filter through a counterpoised filter paper neutral to phenolphthalein, or a weighed Gooch crucible with suction into a dry weighed beaker, protecting the solution during the operation from carbon dioxide and other acid fumes. Wash the residue on the paper or in the crucible with hot neutral alcohol until free from soap. Dry the filter paper or crucible and residue at 100 to 105° C. for three hours, cool, and weigh the total matter insoluble in alcohol. (Since the percentage of the matter insoluble in alcohol is not required under this specification, time may be saved by omitting the drying and weighing and proceeding directly with the moist residue to the determination of matter insoluble in water (3).)

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(4) *Alkali as Alkaline Salts (Total Alkalinity of Matter Insoluble in Alcohol).*—Titrate the filtrate from the determination of matter insoluble in water with standard acid, using methyl orange as indicator. Calculate alkalinity to sodium carbonate ( $\text{Na}_2\text{CO}_3$ ).

(d) **SIEVE TEST.**—Transfer a weighed sample of the insoluble siliceous material to a No. 100 sieve and carefully brush through. Weigh the amount passing through and calculate percentage.

After weighing transfer to a No. 200 sieve and treat in the same manner, weigh the amount passing through, and calculate percentage.

(e) **TOTAL ANHYDROUS SOAP.**—Evaporate the alcoholic solution obtained after filtering off and washing the matter insoluble in alcohol—(c), (1) and (2)—to dryness, dry at  $105^{\circ}\text{C}$ . to constant weight. Report the result as total anhydrous soap.

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(b) **STANDARD SULPHURIC ACID SOLUTION.**—0.5 N, or about 25.8 g strong sulphuric acid (specific gravity = 1.84) diluted to 1 liter. Standardized against standard sodium hydroxide solution (a).

(c) **SULPHURIC ACID (SPECIFIC GRAVITY = 1.53).**—Mix 62.5 cc of sulphuric acid (specific gravity = 1.84) with 61.5 cc of water.

(d) **FEHLING SOLUTION.**—(1) *Copper Sulphate Solution.*—Dissolve 34.639 g of copper sulphate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) in water and dilute to 500 cc.

(2) *Alkaline Tartrate Solution.*—Dissolve 173 g of Rochelle salts ( $\text{NaKC}_4\text{H}_4\text{O}_6 \cdot 4\text{H}_2\text{O}$ ) and 50 g of sodium hydroxide in water and dilute to 500 cc. Mix equal volumes of (1) and (2) immediately before use.

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**CIRCULAR**  
OF THE  
**BUREAU OF STANDARDS**  
S. W. STRATTON, DIRECTOR

No. 133

**DESCRIPTION AND OPERATION OF AN  
ELECTRON-TUBE DETECTOR UNIT FOR  
SIMPLE RADIO RECEIVING OUTFITS**

NOVEMBER 10, 1922



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1922



# DESCRIPTION AND OPERATION OF AN ELECTRON-TUBE DETECTOR UNIT FOR SIMPLE RADIO RECEIVING OUTFITS.<sup>1</sup>

## ABSTRACT.

The apparatus now in use for radio reception, except the most simple types, uses electron tubes. Electron tubes are used for reception in many different kinds of circuits. One of the most elementary uses is as a simple detector. It is also possible to use electron tubes in reception in circuits using various kinds of amplification, or regeneration, beat reception, or other methods. A simple electron-tube detector set will not serve to receive signals transmitted by continuous-wave radio telegraphy. This circular describes a simple electron-tube detector unit and gives a method of operating it. The set with electron-tube detector is more sensitive than a set employing a crystal detector and may be expected to give more satisfactory results.

An antenna, lightning switch, ground connection, and telephone receivers which can be used in this set have been described in Circular No. 120. Tuning devices for use with this electron-tube detector set may be the tuning coil described in Bureau of Standards Circular No. 120 or the two-circuit coupler and variable air condenser described in Bureau of Standards Circular No. 121.

For an electron-tube detector unit it is necessary to have an electron tube, socket for the tube, filament rheostat, grid leak, grid condenser, by-pass condenser, binding posts, and other minor accessories. It is also necessary to have a 6-volt storage battery and a "B" dry battery of 22½ to 45 volts. Most of these parts should be purchased, although some can be made at home if desired. The cost of the complete electron-tube detector unit, including the tube and batteries, may be expected to be from \$23 to \$37. The principal part of this expense is the 6-volt storage battery. This estimate is exclusive of the cost of tuning device and telephone receivers described in Circulars Nos. 120 and 121, which may be from about \$10 to \$20. No estimate is made of the cost of equipment for charging storage batteries.

The electron tube, socket, condensers, filament rheostat, grid leak, and other parts of the detector unit are mounted on a wooden base and panel. The wood for the base and panel should be thoroughly dry and should preferably be protected by a coat of good electrical insulating varnish.

A complete description of the method of assembling and wiring the detector unit is given.

Illustrations are given showing the arrangement of the various parts and the complete assembled detector unit. The method of operating the set is also given.

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<sup>1</sup> This is one of a series of circulars describing radio receiving equipments of very simple type. The previous circulars of the series are Nos. 120 and 121. See Circular No. 120 for statement of the origin and purpose of this series. Each of these publications is obtainable from the Superintendent of Documents, Washington, D. C., at 5 cents per copy.

## 1. INTRODUCTION.

Electron tubes are now used in most radio receiving sets, except the more simple types. Crystal detectors may be used in very simple receiving sets, as described in Bureau of Standards Circulars Nos. 120 and 121. Electron tubes are used for reception in many different kinds of circuits. The simple detector circuit is one of the most elementary. It is also possible to use electron tubes in reception in circuits using various kinds of amplification, or regeneration, beat reception, or other methods. For descriptions of various kinds of tube receiving circuits reference may be made to the book *The Principles Underlying Radio Communication*, or to one of various other books now available, of which a list may be found in Bureau of Standards Circular No. 122, *Sources of Elementary Radio Information*.

This circular describes an electron-tube detector unit which may be used with the single-circuit radio receiving set described in Bureau of Standards Circular No. 120,<sup>2</sup> with the two-circuit radio receiving set described in Bureau of Standards Circular No. 121,<sup>3</sup> or with any other tuning device.

The electron-tube detector unit may be substituted for the crystal detector; that is, its function is the same as the crystal detector, which is to make the signals from the radio transmitting station audible in the telephone receivers when the radio receiving set is tuned to the proper wave frequency (wave length). The use of an electron-tube detector will increase the receiving radius of the receiving set, so that it will be possible to hear high-power transmitting stations at a distance of about 75 miles, provided the transmitting station uses wave frequencies between 500 and 1,500 kilocycles per second (wave lengths between 600 and 200 m.). Under good atmospheric conditions signals from greater distances may be heard, especially at night.

The electron-tube detector unit described in this circular is one step forward in the understanding of more sensitive and complex apparatus. A later circular of this series describing audio frequency amplifiers is in preparation. *The simple electron-tube detector circuit will not make "continuous wave" signals audible.*

<sup>2</sup> Construction and Operation of a Simple Homemade Radio Receiving Outfit, obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., price, 5 cents in cash.

<sup>3</sup> Construction and Operation of a Two-Circuit Radio Receiving Equipment with Crystal Detector, obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., price, 5 cents in cash.

<sup>4</sup> See pages 431 and 501 of the book, *The Principles Underlying Radio Communication* (Signal Corps Radio Communication Pamphlet No. 40). This is a bound volume of over 600 pages, and is obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., price, \$1.



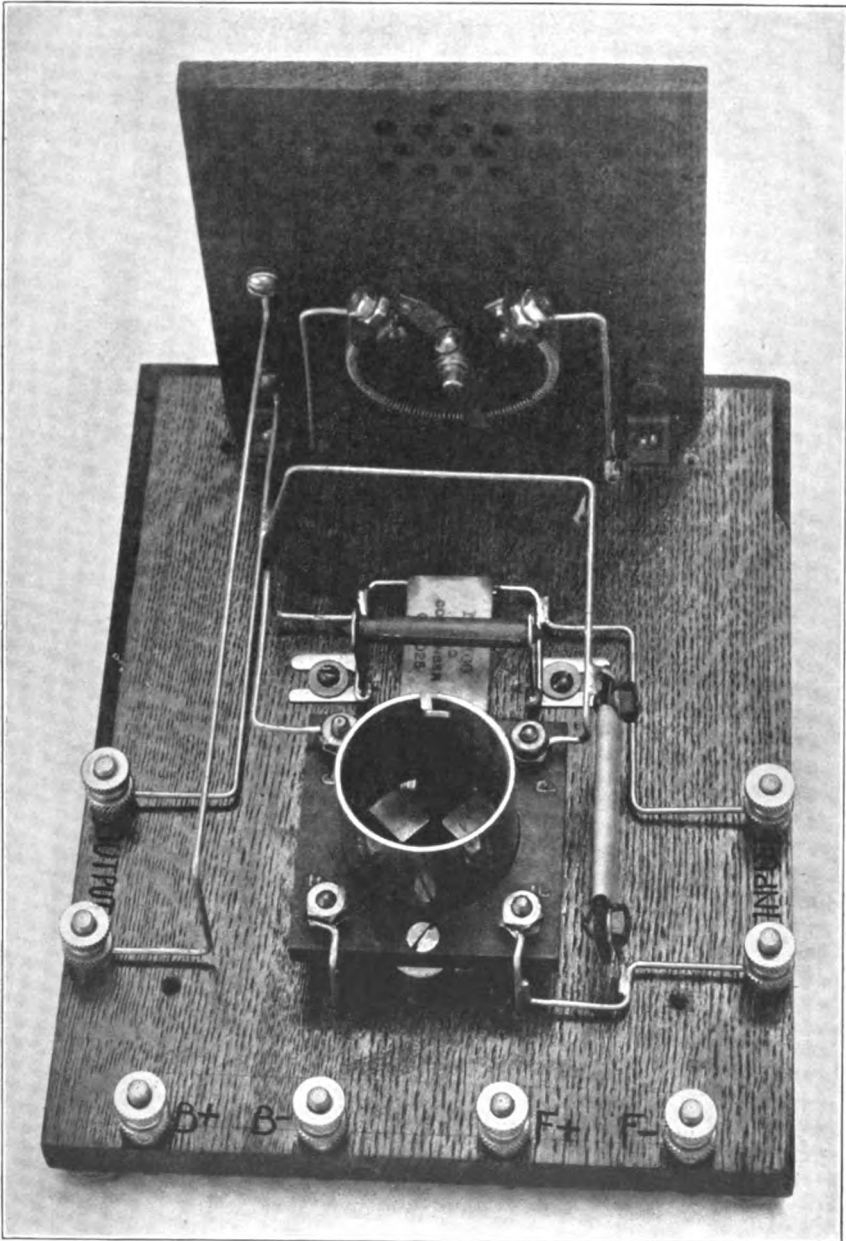


FIG. 2.—Assembled electron-tube detector unit

The cost of an electron-tube detector unit, complete with the necessary batteries, is between \$23 and \$37. The principal part of this expense is a 6-volt storage battery. No estimate is included of the cost of equipment for charging the storage battery.

Additional electron-tube amplifiers (described in subsequent publications), which will greatly increase the sensitivity<sup>6</sup> and hence the receiving range of the receiving set, will not require additional storage batteries. This will make the added cost of the amplifiers comparatively small.

The cost of the tuning equipment and telephone receivers to be used with this detector unit, as described in Bureau of Standards Circulars Nos. 120 and 121, may be from \$10 to \$20.

This publication describes simple apparatus of satisfactory performance without reference to the possible existence of any patents which might cover parts of the apparatus. Apparatus in general similar to that described can be purchased from responsible manufacturers whose announcements can be found in current radio periodicals.

## 2. ESSENTIAL PARTS OF COMPLETE RADIO RECEIVING STATION.

A complete radio receiving station comprises:

ANTENNA, LIGHTNING SWITCH, GROUND CONNECTIONS, AND TELEPHONE RECEIVERS.—These are completely described in Bureau of Standards Circular No. 120.

TUNING DEVICE.—This may be the tuning coil described in Bureau of Standards Circular No. 120, or it may be the two-circuit coupler and variable air condenser described in Bureau of Standards Circular No. 121. While the two-circuit tuning device will be somewhat more selective<sup>6</sup> than the single-circuit tuner, as stated in Circular No. 121, its use is not absolutely essential.

ELECTRON-TUBE DETECTOR UNIT (FIGS. 1, 2, AND 7).—The electron-tube detector unit is composed of a baseboard *B* and an upright panel *A*. On the baseboard *B* is mounted an electron tube *E* (shown only in Fig. 7), an electron-tube socket *S*, a resistor (grid leak) *R*, a grid condenser *C*, a by-pass condenser *C'*, and eight binding posts. On the upright panel *A* is mounted a filament rheostat *R'* (the adjusting knob *J* is shown in fig. 7), and two telephone-receiver binding posts *L* and *M*. The parts *S*, *R*, *C*, and *C'* are also shown in Figure 3. This circular tells how the various parts are assembled on the baseboard and the panel. No

<sup>6</sup> The Principles Underlying Radio Communication, p. 448.

<sup>6</sup> The Principles Underlying Radio Communication, p. 378.

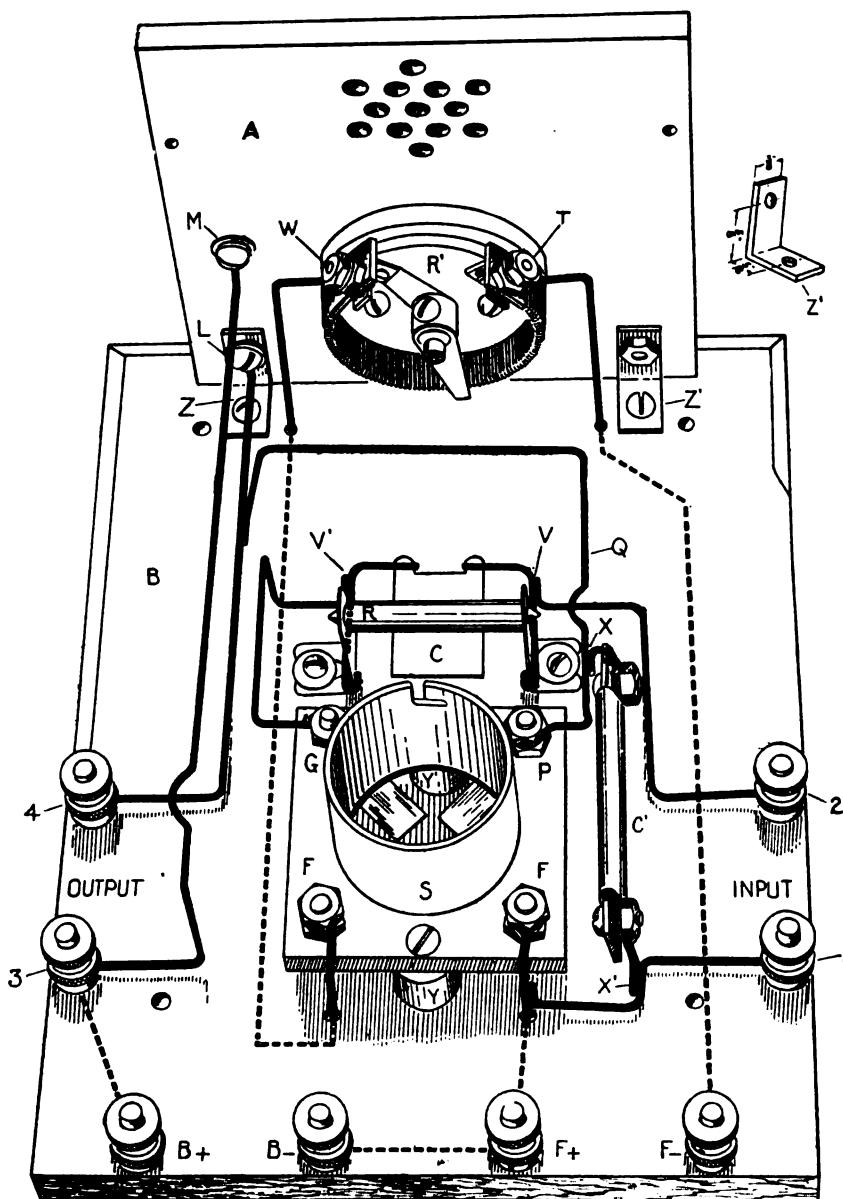


FIG. 1.—Diagram showing location of parts and wiring of electron-tube detector unit.

description is given of how the parts *E*, *S*, and *R'* are made, because they are rather difficult to construct. It is, of course, possible for one to make parts such as the electron-tube socket *S* and the filament rheostat *R'*.

ACCESSORIES.—Under the heading of accessories may be listed a 6-volt battery, used for lighting the filament, often called the "A" battery, having a capacity of about 60 ampere-hours, a 22½ to 45 volt dry battery ("B" battery), binding posts, stiff copper wire, wood boards for the baseboard and upright panel, two brass angle braces for supporting the panel, and miscellaneous screws. The "A" and "B" batteries are shown in Figure 7. The "A" battery will usually be placed on the floor beneath the table upon which the other parts of the equipment are arranged. An insulating material panel may be substituted for the wood if desired. The electron-tube detector may also be entirely inclosed in a wood cabinet with a hinged cover, if desired.

### 3. DESCRIPTION OF PARTS.

BASEBOARD (*B*, FIGS. 1 AND 3).—The baseboard *B* is any kind of dry wood about 6¼ inches by 8¼ inches by ½ inch thick. Eight holes are drilled through the base in which the binding posts are fastened. Spacing of these holes is shown in Figure 3. The baseboard is arranged so that the three remaining sides and a hinged cover may be added without changing the relative positions of the binding posts. Under each of the four corners of the baseboard *B* rubber or wood feet (risers) are fastened in order that the binding-post heads and wiring will be protected on the underside.

UPRIGHT PANEL (*A*, FIGS. 1 AND 4).—The panel *A* is any suitable dry seasoned wood about 4½ by 5 inches by ¾ inch thick. In Figure 4 a back view of the panel is shown which brings the two holes for the telephone-receiver binding posts in the lower left-hand corner. If the panel is viewed from the front, these two holes will be at the lower right-hand corner. It is quite desirable that this panel present a good appearance, it being the front panel. Four holes are drilled in the panel *A*, one for the bolt which fastens the panel to the brace (see *Z'*, Fig. 1), two for the telephone-receiver binding posts *L* and *M* (Figs. 1 and 7), and one for the shaft of the filament rheostat *R'* (see Fig. 1). The exact location of the hole for the rheostat shaft is determined from the rheostat itself. It is drilled so that the rheostat will

occupy as low a position as possible, allowing room enough to do the necessary wiring.

**ELECTRON TUBE (E, FIG. 7).**—The electron-detector tube is a commercially available type. The several parts of an electron tube (sometimes called a vacuum tube) are described in *The Principles Underlying Radio Communication*, Chapter 6.

**ELECTRON TUBE SOCKET (S, FIGS. 1, 2, AND 7).**—The electron-tube socket may be any one of various commercially available types. There are many types available, and the majority of them are found satisfactory for this purpose.

**GRID LEAK AND GRID CONDENSER (R and C, FIGS. 1, 2, AND 7).**—The grid leak and grid condenser are sometimes sold as a unit and sometimes are sold separately, or they may be constructed. If a detector type of electron tube (sometimes called "soft" or "gas" tube) is used, it is better that these two parts be purchased with the tube, care being taken to select the proper values of resistance and capacity for the grid leak and the grid condenser, as specified by the manufacturer of the tube purchased. The resistance of the grid leak will usually be between 1 and 5 megohms (1,000,000 and 5,000,000 ohms) and the capacity of the grid condenser will be about 0.0003 $\mu$ f (300 $\mu$ f). If an amplifier type of electron tube (sometimes called a "hard" tube) is used, the resistance of the grid leak may generally be anywhere within the resistance limits suggested above and the same size of grid condenser used as mentioned above. Small mica condensers of suitable capacity can be purchased cheaply.

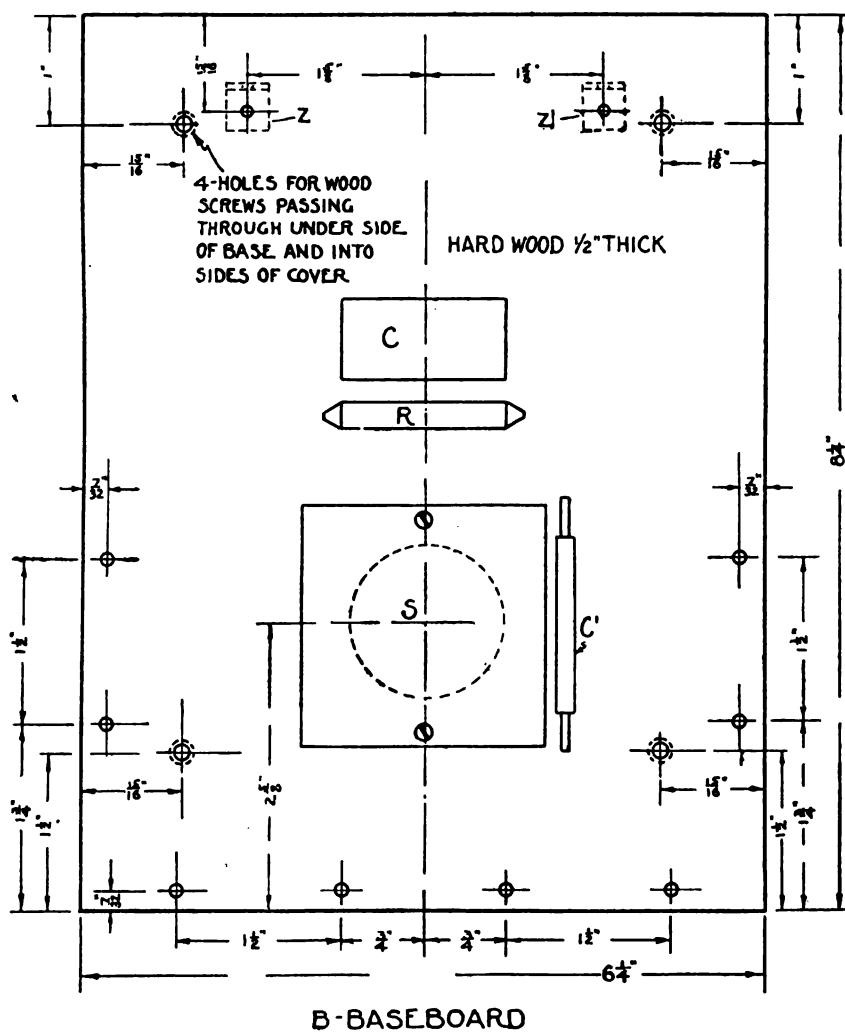
Experimental grid leaks may be made for such electron-tube detectors. This is only suggested for its educational feature. If a two-stage audio-frequency amplifier is used also, it will be quite difficult to make a grid leak that will work satisfactorily. Such an experimental grid leak may be made from a piece of fiber about  $\frac{3}{8}$  inch wide,  $1\frac{1}{2}$  inches long, and from  $\frac{1}{16}$  to  $\frac{1}{8}$  inch thick. Two  $\frac{1}{8}$ -inch holes are drilled along the center line of the piece about 1 inch apart. A line is drawn between the two holes, using india or drawing ink. Contact with the ink line may be made by the use of two brass (6-32 or 8-32) machine screws about  $\frac{1}{2}$  inch long and each equipped with one nut and two washers. The machine screws are put through the holes in the ends of the fiber strip with one washer on each side of the fiber strip. A small

piece of tin foil may be rolled up and wound around each machine screw between the fiber and the washer, so that the tin-foil pad will make contact with the ink line. When the nuts are tightened down, the tin-foil pads will flatten out and form a contact between the brass washers and the ends of the ink line. Since the ink line makes a partial electrical conductor of high resistance, the thickness and width of the ink line will determine the resistance of the grid leak to a great extent. The value of resistance may be decreased by inking the line over several times until the electron-tube detector works best. A suitable grid condenser may be made from tin foil and paraffined paper in the manner described in "Auxiliary Condensers and Loading Coil used with Simple Homemade Radio Receiving Outfits," a circular of the Bureau of Standards now in preparation, the total effective area of the condenser plates being reduced to about 6 square inches. This may be accomplished by using six tin-foil strips  $\frac{3}{8}$  inch wide by 7 inches long instead of those described in the circular mentioned above. The width of the cap and base pieces and the paraffined paper insulating sheets may also be correspondingly reduced to better meet the space requirements of the electron-tube detector set.

**BY-PASS CONDENSER ( $C'$ , FIGS. 1, 2, AND 7).**—This is any small-sized fixed condenser having a capacity of from 0.0003 to 0.0015  $\mu\text{f}$  (300 to 1,500  $\mu\text{mf}$ ) which may be purchased or made according to the description given in the circular mentioned above. While this condenser is not absolutely necessary, its use is advisable.

**BINDING POSTS (FIGS. 1 AND 2).**—The binding posts used on the baseboard may be 6-32 or 8-32 brass machine screws each equipped with two nuts and two washers if regular binding posts are not available. The telephone-receiver binding posts  $L$  and  $M$  (figs. 1 and 7) are of the set-screw type to admit the tips of the telephone-receiver cords.

**FILAMENT RHEOSTAT ( $R'$ , FIG. 1).**—As has been previously stated, the filament rheostat may be constructed, but no suggestions regarding its construction are given here. If the rheostat is purchased, it is desirable to select one designed for panel mounting as well as one having a neat appearing knob and pointer. The rheostat should have a resistance of about 7 ohms and a current-carrying capacity of about  $1\frac{1}{2}$  amperes.



**ACCESSORIES.**—The accessory batteries are commercial articles. The purchaser of a storage battery for lighting the filaments should get full instructions from the dealer for testing and recharging the battery. The dry battery ("B" battery) usually used for the plate circuit can not be recharged. The normal life of a dry battery of reliable manufacture is about six months. Storage batteries for use as "B" batteries are available. Their first cost is greater than that of dry batteries, but they may be recharged.

#### 4. ASSEMBLY AND WIRING.

**WOOD FINISH.**—It is essential in electron-tube sets that the wood be protected from moisture. While the wood base and panel may be treated with paraffin, as suggested in Bureau of Standards Circular No. 120, it is more satisfactory to first dry the wood and then stain and varnish it, using a good varnish, preferably insulating varnish. Shellac is not used. It is rather difficult to give definite suggestions concerning drying and staining of wood. Wood may be put in a warm oven for an hour or so to insure more or less complete drying. A lampblack or carbon pigment stain is not used ordinarily on such radio parts, and it would be well to avoid the use of such stains. The stain and varnish are thoroughly dried before the apparatus is mounted on the wood baseboard and panel.

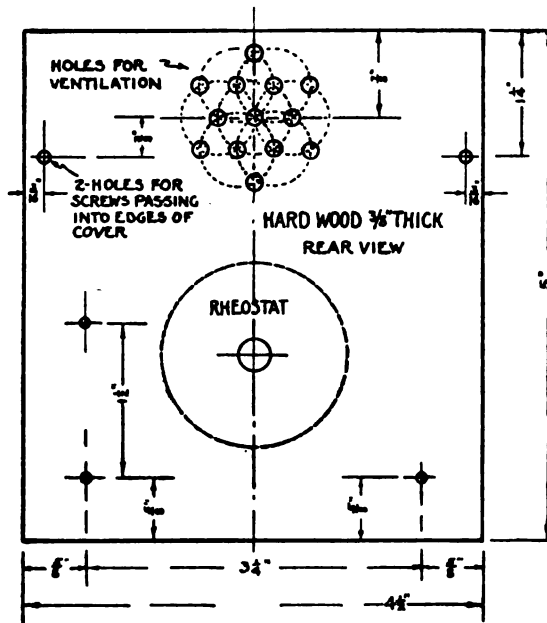
**BASEBOARD (B, FIGS. 1 AND 7).**—The eight brass machine screws or binding posts are put in the holes already drilled in the baseboard. If machine screws are used, the heads are put on the underside of the baseboard, with a brass washer between the head and the baseboard. A brass washer and two nuts are then fastened to each screw, on the upper side of the baseboard, with the washer next to the baseboard. The tube socket *S*, the grid condenser *C*, the grid leak *R*, and the by-pass condenser *C'* are next screwed to the baseboard. (Certain types of condensers will be held in position by the wiring only.) The exact location of these parts can not be stated, because the several types of parts commercially available will vary somewhat in dimensions. One can get a very good idea of the relative positions of the several parts from Figures 1, 2, and 7. The tube socket *S* is mounted so that the two terminals marked *G* and *P* (Fig. 1) are nearest the upright panel. Blocks *Y* and *Y'* are put under the socket *S* so that the four terminals of the socket do not touch the wood baseboard. This is done by cutting off two round wood blocks just long enough to raise the socket terminals clear of the base and mounting them so

that the screws which hold the socket to the baseboard will pass through holes in the centers of the blocks.

After the socket *S*, grid condenser *C*, grid leak *R*, and by-pass condenser *C'* are mounted the parts are wired up. No. 14 bare tinned copper wire is used in wiring. This makes the connections stiff and self-supporting. This wire is ordinarily furnished in rolls. The wire is straightened before it is used. It can be straightened by clamping or otherwise fastening one end solidly and pulling on the other end just hard enough to stretch the wire slightly. (It is also a good plan in wiring such sets to have all wires run as directly as possible, neatly, and all bends made at right angles.) When a wire is attached to a binding post, a loop or eye is formed on the end of the wire and the wire at the eye flattened with a hammer. This gives more contact surface. Special lugs may also be soldered to the ends of the wire before the connection is made.

A small hole is drilled through the baseboard just back of each of the tube-socket terminals marked *F* (see Fig. 1). A short piece of wire is fastened to the right-hand socket terminal marked *F*, and is then led through the small hole in the baseboard to the underside of the baseboard. The same wire is led to the binding post *F* + and fastened between the machine-screw head and washer underneath the baseboard. The same wire is further led to the binding post marked *B* – and fastened between the machine-screw head and washer underneath the baseboard. All wires which are run on the underside of the baseboard are shown in Figure 1 by dotted lines. A short piece of wire is soldered to the wire leading from the right-hand socket terminal marked *F* just above the baseboard and led to the “input” binding post No. 1 and fastened between the washer and the first nut. This wire is shown as a solid line, which means it is on the upper side of the baseboard. The wires do not touch the wood boards except at the terminals and where the wires pass through holes in the baseboard. The wires may be raised more or less to accomplish this.

The two terminals of the grid condenser *C* are connected to the two terminals of the grid leak *R*, as shown in Figure 1. A wire is soldered at *V* and led to the input binding post No. 2. This wire is kept quite close to the baseboard. Another wire is soldered at *V'* and led to the tube-socket terminal marked *G*. The remainder of the wiring is left until the upright panel is assembled and fastened to the baseboard. Suggestions regarding soldering are given later.



A-UPRIGHT PANEL

- 2-BOARDS FOR SIDES  $7\frac{1}{4} \times 5 \times \frac{1}{2}$ "
- 1-BOARD FOR BACK  $5 \times 3\frac{3}{4} \times \frac{1}{2}$ "
- 1-BOARD FOR TOP  $7\frac{1}{4} \times 5\frac{1}{4} \times \frac{1}{2}$ "
- 2-HINGES BUTT  $\frac{3}{4}$ "

FIG. 4.—Upright Panel.

**UPRIGHT PANEL (A, FIGS. 1, 2, AND 7).**—The filament rheostat  $R'$  is mounted on the upright panel  $A$ , so that the two terminals will be in a convenient position for wiring. Two binding posts of the set-screw type  $L$  and  $M$  (Figs. 1 and 7) are inserted in their proper holes and the upright panel mounted in position by bolting it to the two brass angle pieces ( $Z$  and  $Z'$ ) shown in Figures 1, 2, and 3. One of the telephone receiver binding posts  $L$  serves as a bolt. Two small holes are drilled through the baseboard near the two terminals of the filament rheostat  $R'$ .

A wire is run from the "output" binding post marked 4 (Fig. 1) along the upper side of the baseboard to the back of the telephone-receiver binding post marked  $L$ . A wire is fastened to the tube-socket binding post marked  $P$  and from thence led to the back of the telephone-receiver binding post marked  $L$  or else soldered to a convenient place on the wire leading from binding post  $L$ . These wires are shown in Figure 1. A wire is run from the binding post marked 3 to the back of the telephone-receiver binding post marked  $M$ , and a wire is also run from  $B +$  to binding post marked 3, underneath the baseboard. One of the terminals of the bypass condenser  $C'$  is connected at the point  $X$ , and the other terminal of the condenser is connected to the point  $X'$ . The method of making these connections depends to some extent on the particular type of fixed condenser which is used. If the condenser be provided with flexible leads, one of them is soldered at the point  $X$  and the other is likewise connected at the point  $X'$ . If the condenser is provided with lugs, connections are made by bending the wires into the proper shape and soldering thereto.

A wire is run from a filament rheostat binding post marked  $T$  through the hole in the baseboard and thence along the underside of the baseboard to the binding post marked  $F -$ . Most of this wire is shown in Figure 1 by a dotted line. Likewise a wire is run from the rheostat binding post  $W$  underneath the baseboard and up through the left-hand hole in the baseboard at the rear of the electron tube socket  $S$  and connected to the left-hand binding post marked  $F$ . This completes the assembling and wiring of the electron-tube detector unit.

**SPECIAL BINDING POSTS.**—By the addition of two more binding posts properly connected this detector may be used in a "regenerative" circuit when the binding posts are externally connected to a "tickler" coil coupled to the tuner. These binding posts are added to the detector baseboard  $B$  in line with the "input" binding posts Nos. 1 and 2 (see fig. 1). They are  $\frac{7}{32}$  of an inch from

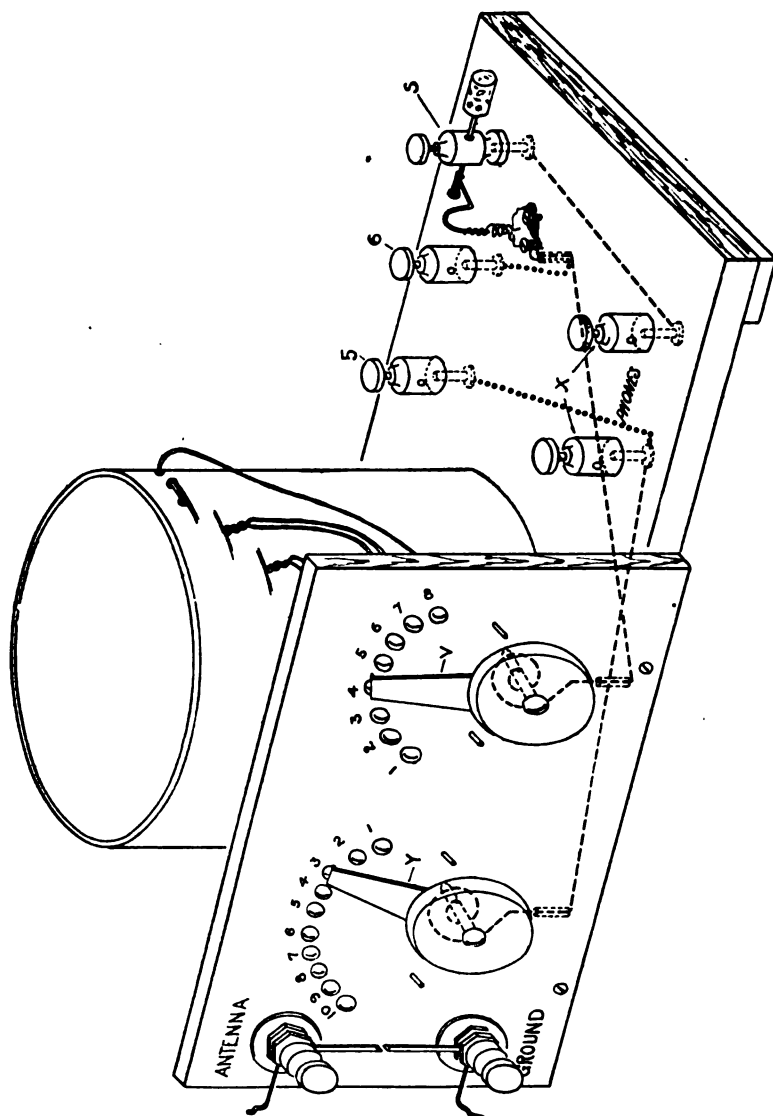


FIG. 5.—Single-circuit radio receiving set described in Circular No. 120, with wiring changes for use with electron-tube detector unit.

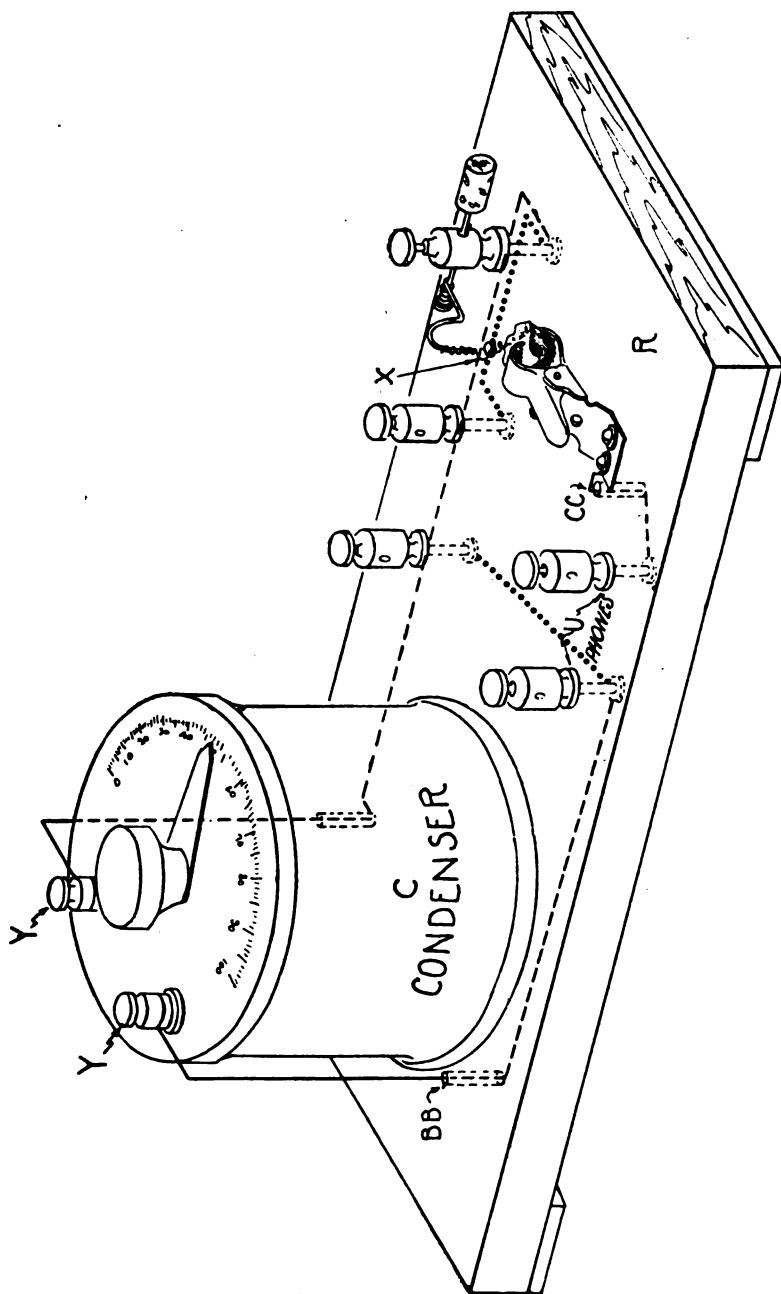


FIG. 6.—Condenser and crystal detector unit of two-circuit receiving set described in Circular No. 121, with wiring changes for use with electron-tube detector unit.

the edge of the baseboard, and the four binding posts are arranged in such a manner that they are equally spaced,  $1\frac{1}{2}$  inches between centers. Referring to Figure 1, the wire which leads from the terminal *P* of the electron-tube socket is cut at some convenient place *Q*, and the two ends thus formed are connected to the extra binding posts. The connection *X*, from one terminal of the condenser *C'*, is also removed and a longer wire connected from this terminal to the other side of the point *Q* where the wire was cut. The method followed in making these connections does, of course, correspond with the style of wiring used in the complete electron-tube detector unit.

#### 5. DIRECTIONS FOR OPERATING.

CONNECTIONS.—It has already been stated that better results are obtained if the two-circuit tuning device described in Bureau of Standards Circular No. 121 is used with the electron-tube detector. However, the single-circuit tuner described in Circular No. 120 may be used, or the electron-tube detector may be connected to any tuner not already supplied with an electron-tube detector. An advantage of the single-circuit receiving set is that it is simpler to adjust.

If the single-circuit tuner is used with this electron-tube detector, the several parts are arranged somewhat as shown in Figure 7. The single-circuit tuner (shown at extreme left) is fully described in Bureau of Standards Circular No. 120. Two more binding posts are added in the back right-hand corner and wired as shown in Figure 5. The greater portion of the wiring is beneath the baseboard. The wires shown as dashes (— — — —) are those already described in Circular No. 120. The wires shown as dots (.....) are the new wires added. Such wiring will not disturb the set for use as a crystal detector receiving set. The second unit to the right is the electron-tube detector described in this circular. Accessory parts, such as telephone receivers, "B" battery, and "A" storage battery, are also shown in Figure 7. As previously mentioned, the "A" battery is shown here reduced in size, and it is usually placed under the table upon which the rest of the apparatus is arranged.

If the two-circuit tuning device is used with this electron-tube detector, the arrangements of the parts is similar to that shown in Figure 7, except that the two units, consisting of the coupler and the variable condenser with crystal detector, replace the single-circuit receiving set shown at the left. Connections between the second

dary of the coupler and the terminals of the variable condenser are the same as described in Bureau of Standards Circular No. 121. Two more binding posts are added at the rear edge of the baseboard supporting the variable condenser and crystal detector (see Fig. 6). The dotted lines indicate the new wiring connections as described for the single-circuit receiving set.

The antenna and ground wires are connected as described in Bureau of Standards Circular No. 120 and as shown in Figure 7. Binding post No. 5 (Fig. 7) is connected to binding post No. 1, and binding post No. 6 is connected to binding post No. 2. The telephone receivers are connected to the binding posts *L* and *M*, as shown in Figure 7. The red (positive+) wire of the "B" battery is attached to the electron-tube detector binding post marked *B* + and the black (negative-) wire to the binding post marked *B* -. An insulated flexible copper wire is run from the red (positive+) terminal of the 6-volt "A" storage battery to binding post marked *F* + (Fig. 7) and a similar wire from the black (negative-) terminal of the "A" battery to the binding post marked *F* -.

OPERATION.—The filament rheostat knob *J* (Fig. 7) is turned to the extreme left, and the electron-tube *E* inserted in the electron-tube socket *S*. The filament rheostat knob is then turned to the right until the electron-tube filament becomes lighted, the brilliancy depending upon the type of electron tube used. When one of the telephone-receiver terminals is removed from its binding post and again touched to the post, a sharp "click" in the telephone receivers will be an approximate indication that the circuit is in working condition. If the test buzzer as described in Bureau of Standard Circular No. 120 is available, it may be attached (as described in that circular) to the tuner binding post marked "ground" and then the rheostat adjusted until the sound in the telephone receivers is the loudest. The electron-tube detector unit is merely substituted for the crystal detector, and the tuning of the receiving circuit is the same as described in Circulars Nos. 120 or 121. When the signals from a desired transmitting station are heard as loud as possible by tuning, the intensity may sometimes be improved by adjusting the knob on the filament rheostat so as to increase or decrease the filament current (current from the "A" battery). The knob is kept in the position of minimum filament current without reducing the strength of the incoming signals.

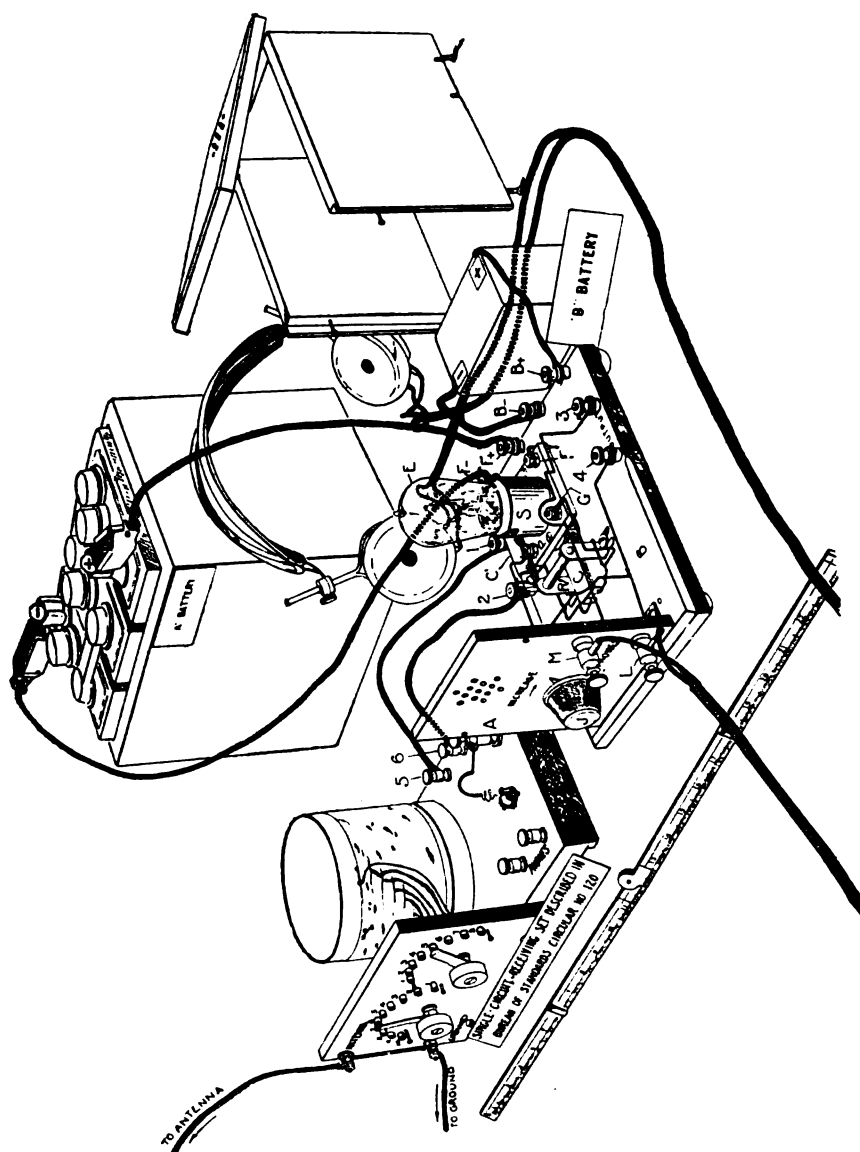


FIG. 7.—Method of connecting simple single-circuit radio receiving set, filament battery, plate battery, and telephone receivers, to the electron-tube detector unit, ready for use.

If a detector type of electron tube be used, the voltage of the "B" battery is changed until the greatest signal intensity is obtained. This necessitates the use of a tapped "B" battery. The operator must not expect too much of the apparatus at the first trial, and even assuming that he has had experience with crystal detectors, some difficulty may be experienced in getting the electron tube to operate. In this case he should first ascertain if the various parts of the complete receiving equipment are properly connected; or, again, it may be found that some of the connections to the electron-tube detector unit are improperly made. Special care should be taken to see that the "A" and "B" batteries are connected to the proper terminals of the electron-tube detector unit. It is especially important to see that the "B" or plate battery is *not* connected to the binding posts marked  $F +$  and  $F -$ . This battery has too high voltage for the electron-tube filament and would burn it out. After a little experience the operator will find the electron tube to be much more positive in adjustments than the crystal detector.

#### 6. NOTES ON SOLDERING.

It has been stated above that certain connections were soldered. In fact, one could well advise that all connections about a radio circuit be soldered, but soldered correctly. There are some general hints that may be given, but judgment and experience are essential. (1) The soldering copper must be clean and the tip well coated with solder. If the tip of the soldering copper is not bright, it should be filed clean. It is then heated, care being taken that the tip is not directly in the flame. After the copper is hot, not red hot, the tip is dipped in the soldering flux or paste and coated with solder. (2) The wires are cleaned where the soldering is to be done, using fine sandpaper, then a small amount of soldering flux or paste is applied at the joint, and the wires to be soldered are tinned or coated with solder before the wires are joined. After the wires are tinned they are soldered together, using just enough solder to make the joint solid. The joint should not be jarred while the solder is still soft. To do so weakens the joint and gives the solder a dull appearance. A good soldered joint will be smooth and bright. (3) All excess soldering flux or paste should be cleaned off. Gasolene or alcohol will assist in cleaning off the paste. This last point is sometimes overlooked, and the excess flux often causes the copper wires to corrode.

**7. APPROXIMATE COST OF PARTS.**

The following list includes the cost of parts of the electron-tube detector unit and the "A" and "B" batteries. It does not include the cost of the telephone receivers or of any of the other equipment used to make up the complete receiving outfit, since this has been given in Bureau of Standards Circulars Nos. 120 and 121.

**Electron-tube detector unit:**

Electron tube.....	\$5. 00 to \$6. 50
Electron-tube socket.....	. 75 to 2. 00
Filament rheostat.....	1. 00 to 2. 50
Grid leak and grid condenser.....	. 50 to 1. 50
By-pass condenser, about.....	. 35 to . 35
Ten feet No. 14 bare tinned copper wire, about.....	. 10 to . 10
Miscellaneous binding posts and screws, about.....	. 75 to . 75

**Batteries:**

"A" storage battery, 6-volt, 60-ampere-hour.....	15. 00 to 20. 00
"B" battery, 22½ to 45 volts.....	1. 00 to 3. 00

Total.....	24. 45 to 36. 70
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WASHINGTON, August 16, 1922.



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DEPARTMENT OF COMMERCE.

BUREAU OF STANDARDS.

S. W. STRATTON, Director.

U.S.

CIRCULAR OF THE BUREAU OF STANDARDS.

No. 134.

[SEPTEMBER 16, 1922.]

UNITED STATES GOVERNMENT SPECIFICATION FOR  
FIRE-EXTINGUISHING LIQUID (CARBON TETRA-  
CHLORIDE BASE).<sup>1</sup>

U.S. FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION NO. 36.

This Specification was officially adopted by the Federal Specifications Board, on July 3, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of materials covered by it.

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1. GENERAL.

The liquid shall be capable of extinguishing fires caused by the burning of inflammable liquids and solids, shall be a nonconductor of electricity, and shall consist of carbon tetrachloride containing other suitable products necessary to produce a liquid conforming to the following requirements when tested according to the methods herein stated:

APPEARANCE.—It shall be a clear, homogeneous, mobile liquid.

SPECIFIC GRAVITY.—The specific gravity at 15.5/15.5° C. shall not be less than 1.500.

COLD TEST.—The liquid must have a cold test not higher than minus 45.5° C. (minus 50° F.).

<sup>1</sup> The fumes generated in extinguishing fire with this liquid are intensely irritating and are also poisonous, and it is unsafe for use in confined spaces. On account of the rapid generation of such fumes, a fire can not be fought for any considerable length of time. However, this material is the only suitable liquid known, which is a nonconductor of electricity, for use in hand-fire extinguishers in fighting incipient fires in connection with electrical apparatus. Care should be exercised in its use.

**DISTILLATION.**—Not over 2 per cent shall distil below 60° C. At least 90 per cent shall distil between 70 and 80° C. At least 99 per cent shall distil below 100° C.

**IMPURITIES.**—The liquid shall be free from nitrobenzene, water, acid or alkali, and free halogens, and shall not contain more than 1 per cent by weight of carbon disulphide. It shall not corrode metals used in fire extinguishers.

## 2. SAMPLING.

No samples shall be submitted with bids. It is mutually agreed by buyer and seller that a single container (sealed can of not more than 1 gallon capacity) out of each lot of not more than 1,000 containers (sealed can of not more than 1 gallon capacity) shall be taken as representative of the whole, and sent unopened to the laboratory for test. When for any reason this is not done, the inspector shall thoroughly mix the contents of the container sampled, transfer not less than 1 quart to a clean, dry glass bottle or tin can, which must be nearly filled with the sample, securely stoppered with a new clean cork or well-fitting cover or cap, sealed, and distinctly labeled by the inspector, and sent to the laboratory for test.

## 3. METHODS OF TESTING.

**APPEARANCE.**—The sample, thoroughly shaken in the original container and immediately poured into a clean, dry glass vessel, shall not show any turbidity.

**SPECIFIC GRAVITY.**—Specific gravity shall be determined by any convenient method accurate to the third decimal place.

**COLD TEST.**—The apparatus used for this test shall consist of a 1 by 8 inch test tube supported in a larger tube about 1 1/4 inches in diameter. The inner tube shall be provided with a stopper carrying a low-temperature thermometer graduated in degrees to minus 60° C. or below, and a wire bent into a loop at the lower end, which serves as a stirrer. Twenty-five cubic centimeters of the liquid to be tested shall be placed in the inner tube and then the whole slowly immersed in the cooling bath contained in a Dewar vacuum bottle. The liquid shall be kept in constant and vigorous agitation by means of the stirrer, taking frequent temperature readings as the sample cools. The lowest temperature at which the material flows shall be taken as the cold test of the liquid. The cooling bath should not be higher than minus 60° C. and for this purpose liquid air is recommended. However, a suitable

bath may be obtained by mixing carbon dioxide snow with gasoline to form a mixture of a thick mushy consistency. The carbon dioxide snow can be readily obtained from the ordinary cylinders in which it is furnished commercially by holding a felt sack or several layers of towel over the mouth of the valve, tilting the cylinder until the liquid carbon dioxide can flow out, and opening the valve.

**DISTILLATION.**—The apparatus used for this test shall consist of a standard 100 cc Engler flask, an accurately graduated thermometer having a range of from 0° C. to not less than 120° C., a suitable water-cooled condenser, and an accurately graduated 100 cc cylinder.

**PROCEDURE.**—(a) The condenser tube shall be swabbed to remove any liquid remaining from a previous test. A piece of soft cloth attached to a cord or copper wire may be used for this purpose.

(b) The bulb of the thermometer shall be uniformly covered with long-fiber absorbent cotton weighing not less than 3 nor more than 5 mg. A fresh portion of clean cotton shall be used for each distillation.

(c) One hundred cubic centimeters of the sample shall be transferred to the Engler flask, taking care that none of the liquid shall be permitted to flow into the vapor tube.

(d) The thermometer provided with a cork shall be fitted tightly into the flask so that it will be in the middle of the neck and so that the lower end of the capillary tube is on a level with the inside of the bottom of the vapor outlet tube at its junction with the neck of the flask.

(e) The flask shall be supported on a plate of asbestos 20 cm in diameter, having an opening 4 cm in diameter in its center. The flask and burner shall be surrounded with a shield to prevent fluctuation in the temperature of the neck of the flask.

(f) The vapor outlet tube shall be connected by means of a cork to the condenser tube. The vapor tube shall extend into the condenser tube from 2 to 5 cm.

(g) When everything is in readiness, heat shall be applied with an open flame at a uniform rate, so regulated that the first drop of condensate falls from the condenser into the 100 cc cylinder in not less than 5 nor more than 10 minutes. The heat shall then be so regulated that the distillation will proceed at a uniform rate of not less than 4 nor more than 5 cc per minute. The volume of distillate shall be recorded at 60, 70, 80, and 100° C.

IMPURITIES.—(a) *Water*.—Five cubic centimeters of the well-shaken sample shall be transferred to a test tube and a small piece of *clean*, metallic sodium added; no gas should be evolved from the surface of the metal. The appearance of the solution shall also be noted. Turbidity indicates the presence of water (owing to the insolubility of sodium hydroxide in carbon tetrachloride).

(b) *Neutrality*.—Twenty-five cubic centimeters of the liquid shall be thoroughly shaken with an equal volume of water and allowed to settle. Small pieces of sensitive red and blue litmus paper put in the aqueous layer shall not indicate an acid or alkaline reaction.

(c) *Free halogens*.—No color shall be produced when 25 cc of the liquid is thoroughly shaken with an equal volume of 10 per cent potassium iodide solution containing starch as an indicator.

(d) *Nitrobenzene*.—The original sample or any fraction thereof obtained by distillation must have no odor of nitrobenzene.

(e) *Carbon disulphide*.—Radcliffe's method:<sup>2</sup> Twenty-five cubic centimeters of about 2 *N* alcoholic potassium hydroxide solution shall be transferred to a flask of suitable size, the flask loosely stoppered with a cork and weighed. One cubic centimeter of the sample shall be added by means of a pipette, the cork replaced, and the flask again weighed, obtaining the weight of the sample taken. The mixture shall stand at room temperature for five minutes and then be rendered slightly acid with dilute acetic acid, using phenolphthalein as indicator. The mixture shall be diluted with water, cooled thoroughly, and an excess of solid sodium bicarbonate added. The milky, turbid mixture shall then be titrated with 0.1 *N* iodine solution, using starch solution as indicator, and the percentage by weight of CS<sub>2</sub> calculated (1 atom I = 1 molecule CS<sub>2</sub>).

(f) *Corrosion*.—Satisfactory corrosion tests can not be made in a short time, but the Government reserves the right to reject bids for material that has been found corrosive in service.

(g) *Conductivity test*.—A standard voltmeter having 100 ohms per volt of its scale shall be connected in series with a 110-volt circuit and two electrodes consisting of parallel copper wires 5 cm long and spaced 2.5 mm apart immersed in the liquid to be tested. On closing the circuit there shall be no appreciable motion of the needle.

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<sup>2</sup>J. Soc. Chem. Ind., 28, p. 229: 1909.

Physics

AUG 5 1924

U. S. Gov't  
Master  
Specification,  
No. 36a

DEPARTMENT OF COMMERCE

BUREAU OF STANDARDS

George K. Burgess, Director

CIRCULAR OF THE BUREAU OF STANDARDS, No. 134

[2d ed. June 20, 1924]

UNITED STATES GOVERNMENT MASTER SPECIFICATION FOR  
FIRE-EXTINGUISHING LIQUID (CARBON TETRA-  
CHLORIDE BASE)

FEDERAL SPECIFICATIONS BOARD, SPECIFICATION No. 36a

[Revision adopted June 1, 1924]

This specification was officially adopted by the Federal Specifications Board on July 3, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of fire-extinguishing liquid (carbon tetrachloride base).

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I. TYPE

The material covered by this specification is intended for use with hand-chemical fire extinguisher (1-quart-carbon-tetrachloride type), Federal Specifications Board Specification No. 124.

103718°—24†—1

### 1. PRECAUTION

The fumes generated in extinguishing fire with this liquid are intensely irritating and are also poisonous. Care should, therefore, be exercised when using it in confined spaces. On account of the rapid generation of such fumes, a fire can not be fought for any considerable length of time in confined spaces. However, this material is the only suitable liquid known, which is a nonconductor of electricity, for use in hand-fire extinguishers in fighting incipient fires in connection with electrical apparatus.

## II. MATERIAL AND WORKMANSHIP

No details.

### III. GENERAL REQUIREMENTS

The liquid shall be capable of extinguishing fires caused by the burning of inflammable liquids and solids, shall be a nonconductor of electricity, and shall consist of carbon tetrachloride containing other suitable products necessary to produce a liquid conforming to the following requirements when tested according to the methods herein stated.

## IV. DETAIL REQUIREMENTS

### 1. APPEARANCE

It shall be a clear, homogeneous, mobile liquid.

### 2. SPECIFIC GRAVITY

The specific gravity at 15.5/15.5° C. shall be not less than 1.50.

### 3. COLD TEST

The liquid must have a cold test not higher than minus 45.5° C. (minus 50° F.).

### 4. DISTILLATION

Not over 2 per cent shall distill below 60° C. At least 90 per cent shall distill between 70 and 80° C. At least 99 per cent shall distill below 100° C.

### 5. IMPURITIES

The liquid shall be free from nitrobenzene, water, acid, or alkali, and free halogens, and shall not contain more than 1 per cent, by weight, of carbon disulphide. It shall not corrode brass, lead, or other material of equal corrosion-resisting properties.

## V. METHOD OF INSPECTION AND TESTING

### 1. SAMPLING

No samples shall be submitted with bids. It is mutually agreed by buyer and seller that a single container (sealed can of not more than 1-gallon capacity) out of each lot of not more than 1,000 containers (sealed can of not more than 1-gallon capacity) shall be taken as representative of the whole, and sent unopened to the laboratory for test. When for any reason this is not done, the inspector shall thoroughly mix the contents of the container sampled, transfer not less than 1 quart to a clean, dry, glass bottle or tin can, which must be nearly filled with the sample, securely stoppered with a new clean cork or well-fitting cover or cap, sealed, and distinctly labeled by the inspector, and sent to the laboratory for test.

### 2. METHODS OF TESTING

(a) **APPEARANCE.**—The sample, thoroughly shaken in the original container and immediately poured into a clean, dry, glass vessel, shall not show any turbidity, sediment, or water.

(b) **SPECIFIC GRAVITY.**—Specific gravity shall be determined by any convenient method accurate to the third decimal place.

(c) **COLD TEST.**—The apparatus used for this test shall consist of a 1 by 8 inch test tube supported in a larger tube about 1½ inches in diameter. The inner tube shall be provided with a stopper carrying a low-temperature thermometer graduated in degrees to minus 60° C. or below, and a wire bent into a loop at the lower end, which serves as a stirrer. Twenty-five cubic centimeters of the liquid to be tested shall be placed in the inner tube and then the whole slowly immersed in the cooling bath contained in a Dewar vacuum bottle. The liquid shall be kept in constant and vigorous agitation by means of the stirrer, taking frequent temperature readings as the sample cools. The lowest temperature at which the material flows shall be taken as the cold test of the liquid. The temperature of the cooling bath should not be higher than minus 60° C. and for this purpose liquid air is recommended. However, a suitable bath can be obtained by mixing carbon dioxide snow with gasoline to form a mixture of a thick mush consistency. The carbon dioxide snow can be readily obtained from the ordinary cylinders in which it is furnished commercially, by holding a felt sack or several layers of towel over the mouth of the valve, tilting the cylinder until the liquid carbon dioxide can flow out, and opening the valve.

(d) **DISTILLATION.**—The apparatus used for this test shall consist of a standard 100 cc Engler flask, an accurately graduated thermometer having a range of from 0° C. to not less than 120° C., a suitable water-cooled condenser, and an accurately graduated 100 cc cylinder.

*Procedure.*—(a) The condenser tube shall be swabbed to remove any liquid remaining from a previous test. A piece of soft cloth attached to a cord or copper wire may be used for this purpose.

(b) The bulb of the thermometer shall be uniformly covered with long-fiber absorbent cotton weighing not less than 3 nor more than 5 mg. A fresh portion of clean cotton shall be used for each distillation.

(c) One hundred cubic centimeters of the sample shall be transferred to the Engler flask, taking care that none of the liquid shall be permitted to flow into the vapor tube.

(d) The thermometer provided with a cork shall be fitted tightly into the flask so that it will be in the middle of the neck and so that the lower end of the capillary tube is on a level with the inside of the bottom of the vapor outlet tube at its junction with the neck of the flask.

(e) The flask shall be supported on a plate of asbestos 20 cm in diameter, having an opening 4 cm in diameter in its center. The flask and burner shall be surrounded with a shield to prevent fluctuation in the temperature of the neck of the flask.

(f) The vapor outlet tube shall be connected by means of a cork to the condenser tube. The vapor tube shall extend into the condenser tube from 2 to 5 cm.

(g) When everything is in readiness, heat shall be applied with an open flame at a uniform rate, so regulated that the first drop of condensate falls from the condenser into the 100 cc cylinder in not less than 5 nor more than 10 minutes. The heat shall then be so regulated that the distillation will proceed at a uniform rate of not less than 4 nor more than 5 cc per minute. The volume of distillate shall be recorded at 60, 70, 80, and 100° C.

(e) *IMPURITIES.*—(1) *Water.*—Five cubic centimeters of the well-shaken sample shall be transferred to a test tube and a small piece of *clean*, metallic sodium immediately added; no gas should be evolved from the surface of the metal. The appearance of the solution shall also be noted. Turbidity indicates the presence of water (owing to the insolubility of sodium hydroxide in carbon tetrachloride).

(2) *Neutrality.*—Twenty-five cubic centimeters of the liquid shall be thoroughly shaken with an equal volume of water and allowed to settle. Small pieces of sensitive red and blue litmus paper put in the aqueous layer shall not indicate an acid or alkaline reaction.

(3) *Free halogens.*—No color shall be produced when 25 cc of the liquid is thoroughly shaken with an equal volume of 10 per cent potassium iodide solution containing starch as an indicator.

(4) *Nitrobenzene.*—The original sample or any fraction thereof obtained by distillation must have no odor of nitrobenzene.

(5) *Carbon disulphide*.—Radcliffe's method:<sup>1</sup> Twenty-five cubic centimeters of about 2 *N* alcoholic potassium hydroxide solution shall be transferred to a flask of suitable size, the flask loosely stoppered with a cork and weighed. One cubic centimeter of the sample shall be added by means of a pipette, the cork replaced, and the flask again weighed, to obtain the weight of the sample taken. The mixture shall stand at room temperature for five minutes and then be rendered slightly acid with dilute acetic acid, using phenolphthalein as indicator. The mixture shall be diluted with water, cooled thoroughly, and an excess of solid sodium bicarbonate added. The milky, turbid mixture shall then be titrated with 0.1 *N* iodine solution, using starch solution as indicator, and the percentage by weight of CS<sub>2</sub> calculated (1 atom I = 1 molecule CS<sub>2</sub>).

(6) *Corrosion*.—Satisfactory corrosion tests can not be made in a short time, but the Government reserves the right to reject bids for material that has been found corrosive in service.

(7) *Conductivity test*.—A voltmeter having approximately 100 ohms per volt of its scale (about 150-volt scale) shall be connected in series with a 110-volt circuit and two electrodes consisting of parallel copper wires 5 cm long and spaced 2.5 mm apart immersed in the liquid to be tested. On closing the circuit there shall be no appreciable motion of the needle.

## VI. PACKING AND MARKING

No details.

## VII. ADDITIONAL INFORMATION

### 1. BASIS OF PURCHASE

The material shall be purchased by weight or volume. The volume will be corrected to a standard temperature of 15.5° C. (60° F.), it being mutually agreed that this correction shall be based on a coefficient of expansion of 0.0012 per degree centigrade (or 0.00067 per degree Fahrenheit). A gallon of fire-extinguishing liquid shall mean 231 cubic inches at 15.5° C. (60° F.). The contract shall state the unit on which purchases are to be based; for example, quart, gallon, pound, 100 pounds, etc.

### 2. CALCULATION OF WEIGHT AND VOLUME

(a) *WEIGHT*.—A gallon of fire-extinguishing liquid at 15.5° C. (60° F.) weighs not less than 12.49 pounds. The exact weight in pounds per gallon of any sample can be determined by multiplying the specific gravity at 15.5/15.5° C. (60/60° F.) by 8.33. Example: If the specific gravity at 15.5° C. is 1.5832, the weight per gallon at this temperature will be  $1.5832 \times 8.33 = 13.188$  pounds.

<sup>1</sup> J. Soc. Chem. Ind., 28, p. 229; 1909.

(b) **VOLUME.**—The volume paid for shall be the volume corrected to a standard temperature of 15.5° C. (60° F.). The correction shall be made by deducting from (when the temperature of gauging is above 15.5° C.) or adding to (when the temperature of gauging is below 15.5° C.) the volume as gauged. Such deduction or addition shall be computed on the basis of a coefficient of expansion of 0.0012 per degree centigrade (or 0.00067 per degree Fahrenheit). Example: If the temperature at which the fire-extinguishing liquid is gauged is 75° F. and the volume delivered (at that temperature) is 100 quarts, then  $0.00067 \times 15 \times 100$  equals the quantity in quarts which must be subtracted from 100 quarts to give the true volume in quarts at 60° F. If the temperature at which the fire-extinguishing liquid is gauged is 10° C., then  $0.0012 \times 5.5 \times 100$  equals the quantity in quarts which must be added to the gauged volume of 100 quarts to give the true volume in quarts at 15.5° C.

### VIII. GENERAL SPECIFICATIONS

No details.

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U.S. DEPARTMENT OF COMMERCE

# CIRCULAR

OF THE

## BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 135

CAUSTIC MAGNESIA CEMENT

OCTOBER 16, 1922



PRICE, 5 CENTS

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## CAUSTIC MAGNESIA CEMENT.

(Also called magnesite cement, magnesia cement, magnesium oxychloride cement, Sorel cement, plastic magnesia cement, and light calcined magnesia cement.)

### ABSTRACT.

A brief summary of the discovery, early history, and later application of the reaction of caustic magnesia with solutions of magnesium chloride. The result of this reaction produces a quick-hardening cement used in the stucco, flooring, and ship decking trade. Short descriptions are given of the ore used, of methods of calcining the ore, also suggested formulas for several types of products, the general qualities of these, and the lines along which specifications for the cement are being developed.

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### I. INTRODUCTION.

Although the cementing material produced by the reaction of magnesite calcined at a low temperature with a solution of magnesium chloride has been known for somewhat more than half a century, its commercial utilization has been decidedly hampered by the secrecy maintained by those who have made a commercial success of its use. The products of caustic magnesia cement are before the public under numerous proprietary names, frequently with no indication as to the essential ingredients. This especially accounts for the general lack of familiarity by the public with the material and the narrowness of the field of application in the building industry.

Within recent years the public has begun to realize its value and its limitations, and also the general similarity between the variously named products; consequently there has been an increase in its use. However, a greater general knowledge of the material

and the industry is needed to further its proper growth. This is the intent of this circular—the furnishing of a convenient source of general information on the subject of caustic magnesia cement, and not an attempt to add to the information already collected by those in close touch with the industry.

The title of the paper and the use of the term “caustic magnesia” has been adopted after considerable thought. The more commonly used name for the cement is “plastic magnesite.” But this is obviously a misnomer, as it is not magnesite but magnesia. The former is the mineralogical name of the carbonate of magnesium and after calcination its residue is oxide of magnesium or magnesia. If the mineral is calcined at a low temperature, the resulting oxide is both plastic and caustic; that is, when mixed with water it produces a sticky mass which is strongly alkaline. In view of the inability to properly define the term “plastic” when applied to such products, it was deemed more advisable to use the term “caustic,” which is a term understood by the general public and the trade and serves to distinguish that oxide of magnesium suitable for cement from that calcined at a higher temperature which reacts with water but very slowly to cause the solution to become caustic or alkaline. It might have been desirable to have used the name “Sorel cement” as an honor to the one who first noted the cementing value of the result of the reaction of the oxide and a solution of the chloride of magnesium. But a name which will indicate the nature or composition of a product should be conceded to be the most desirable.

## **II. EARLY HISTORY AND CHEMISTRY OF CAUSTIC MAGNESIA CEMENT.**

Possibly the first reference to the use of magnesia as a cement is that contained in the English translation by Capt. J. T. Smith of Vicat's “A Practical and Scientific Treatise on Calcareous Mortars and Cements.” Vicat, whose name has been connected with the earliest investigations of cement and is still familiar to cement testers through the “Vicat needle,” published his treatise in 1818. In the translation published by Captain Smith in 1837 the translator has added an appendix to the discussion dealing with the effect of magnesia in calcareous cements, part of which is as follows:

Extensive beds of the native carbonate of magnesia have been recently discovered in the south of India, near Salem and Trichinopoly, in the Madras Presidency, and the supply is so abundant that measures have been already taken for turning this

valuable material to account as a cement, for which purpose the experiments of Colonel Pasley have shown it to be admirably adapted. Some varieties of the mineral are so hard, previous to calcination, as to strike fire with steel; others are of a softer description. The constituents of a specimen analyzed by my friend Dr. Malcolmson, of the Madras medical service, to whose kindness I am indebted for the following particulars, are, in 100 grains, magnesia  $47\frac{1}{2}$ , carbonic acid  $51\frac{1}{2}$ , water one-half, and silica one-half, the proportion of the last ingredient varying in the different samples within very narrow limits. After calcination the magnesia does not slake like lime, but when powdered and made into a paste a sensible heat is extricated; it is capable of hardening under water, though it is preferable to allow it to dry for 12 hours or more previous to immersion. In time it acquires a firm consistency, and even as a common stucco it has been described as of "extreme hardness." An admixture of not more than one and a half times its bulk of clean sand is found to improve its qualities for general purposes, at the same time that it diminishes its cost, but the proportion of such alloy must, of course, be regulated by the use for which the mixture is intended. As a stucco it is considered the most beautiful of all cements, and that even at Madras, where the chunam,<sup>1</sup> so long celebrated, is made in the greatest perfection.

It is not known whether magnesia is still used in India in this manner or not, though India still continues to be an important source of the cement. At the present time in other countries the caustic magnesia is not mixed or gaged with water but with a solution of chloride of magnesium.

In 1867 Stanislaus Sorel,<sup>2</sup> a French civil engineer, announced the discovery of magnesium oxychloride cement. A few years previous to this he had discovered zinc oxychloride cement, which has been used since for fillings in teeth. The former was produced by calcining magnesite and wetting the product with a solution of magnesium chloride (20 to 30° B.) This mixture set to a hard dense mass, the stronger solutions giving the harder cements. With suitable admixtures, a product was formed having the hardness and appearance of marble. He stated that the magnesium chloride could be replaced by a number of other salts, but that the chloride produced the hardest cement.

Though Sorel did no work to determine the chemical constitution of this cement, he suggested that it was a mixture of oxychlorides. The first account of an investigation of the constitution was published in 1870 by Bender,<sup>3</sup> who found the formula of cement which had been stored in air for six months to be  $\text{MgCl}_2 \cdot 5\text{MgO} \cdot 17\text{H}_2\text{O}$ . After treating this with cold water the compound  $\text{MgCl}_2 \cdot 9\text{MgO} \cdot 24\text{H}_2\text{O}$  remained. The original com-

<sup>1</sup> A lime stucco, to the top coat of which is added white of egg, butter fat, milk curd, and soapstone. It is polished by rubbing with soapstone blocks. The first coat is composed of lime, small shells, or sand, and gaged with brown sugar water; the second coat is the same but, sugar is not used; top coat is applied thin before second coat has set.

<sup>2</sup> C. R., 65, p. 102.

<sup>3</sup> Ann. d. Chemie, 159, p. 341.

pound treated with boiling water gave the formula  $2\text{MgO} \cdot 3\text{H}_2\text{O}$ . Following this publication, a great variety of formulas were suggested by different investigators as results of as many different methods employed. Some of these are outlined very briefly below:

Krause and Nuhman,<sup>4</sup> respectively, separated the compounds  $\text{Mg}(\text{OH})\text{Cl} \cdot 4\text{Mg}(\text{OH})_2 \cdot 5\text{H}_2\text{O}$  and  $\text{Mg}(\text{OH})\text{Cl} \cdot 5\text{Mg}(\text{OH})_2$ .

Andre<sup>5</sup> boiled 20 g. of calcined magnesia in a solution of 400 g. of magnesium chloride 500 g. of water, filtered and cooled. The filtrate deposited needles of  $\text{MgCl}_2 \cdot \text{MgO} \cdot 16\text{H}_2\text{O}$ . This salt is decomposed by water and alcohol.

The crystalline deposit frequently formed in a magnesia mixture was found by Davis to be  $\text{MgCl}_2 \cdot 5\text{MgO} \cdot 13\text{H}_2\text{O}$ . On washing the crystals with a large quantity of water they became hydrated magnesium oxide.

Robinson and Waggeman found the normal composition of this oxychloride to be  $3\text{MgO} \cdot \text{MgCl}_2 \cdot 10\text{H}_2\text{O}$ . The oxychlorides prepared by Andre, Davis, and Krause were shown by Fahrman<sup>6</sup> to be identical and of the composition  $3\text{MgO} \cdot \text{MgCl}_2 \cdot 7\text{H}_2\text{O}$ . By electrolysis of a magnesium chloride solution Hoff<sup>7</sup> collected about the cathode a white solid of the composition  $\text{MgCl}_2 \cdot 5\text{MgO} \cdot 14\text{H}_2\text{O}$ . Kallenuer<sup>8</sup> considered that the cement was not an oxychloride, but a solid solution of magnesium chloride in magnesium hydroxide from the fact that the magnesium chloride can be entirely washed out, leaving a hard residue, and from thermochemical data (not published) which he had obtained.

In connection with this, it may be interesting to examine a recent analysis of a magnesite stucco which was placed in an experimental panel at this bureau during 1916. This analysis was as follows:

	Per cent.
"Sand," (insoluble in HCl).....	61.77
$\text{R}_2\text{O}_3$ .....	.17
$\text{CaO}$ .....	.83
$\text{MgCl}_2$ .....	3.38
$\text{MgO}$ .....	16.50
$\text{CO}_2$ .....	3.84
Loss at $110^\circ \text{C}$ .....	4.51
Combined water (by difference).....	9.00

<sup>4</sup> Chemischer Zeitung, 25, p. 96.

<sup>5</sup> C. R., 94, p. 444.

<sup>6</sup> Munchen, Tonindustrie Zeitung, 35, pp. 265-266.

<sup>7</sup> Chemischer Zeitung, 33, pp. 693-694.

<sup>8</sup> Chemischer Zeitung, 33, p. 871.

The percentage composition of the cementing portion is as follows:

	Per cent.
R <sub>2</sub> O <sub>3</sub> .....	0.44
CaO.....	2.28
MgCl <sub>2</sub> .....	8.84
MgO.....	43.15
CO <sub>2</sub> .....	10.05
Loss at 110° C.....	11.79
Combined H <sub>2</sub> O (by difference).....	23.45

Although little is known about the original material, as it now occurs in the panel, it appears from computation and comparison with other stucco mixtures that the MgCl<sub>2</sub> content in the weathered stucco is lower and the CO<sub>2</sub> content is higher than originally. This indicates that MgCl<sub>2</sub> has been leached out and that CO<sub>2</sub> from the atmosphere has combined with a magnesium compound. It is still a question as to what effect this gradual change will have upon the structure of the stucco, which at the present time is generally most satisfactory.

### III. MAGNESITE.

#### 1. OCCURRENCE.

Practically all caustic magnesia used in other than the heat insulating trade is made by calcining magnesite. This mineral is found in many parts of the world, but many of the deposits are comparatively small. Probably the most notable deposits abroad are those in Austria, Czechoslovakia, Greece, and India. Very large deposits occur in New South Wales, New Caledonia, and Portuguese West Africa. Large quantities have been found on the island of Margarita near Venezuela and on the island of Santa Margarita in Magdalena Bay. Some large deposits of a crystalline high-lime magnesite occur in eastern Canada, while large deposits of amorphous magnesite and hydromagnesite have been reported in British Columbia.

In this country, magnesite has been found in Maryland, New Jersey, Massachusetts, New York, North Carolina, Pennsylvania, Nevada, California, and Washington. The only deposits of much commercial value at present are those in California and Washington. That in Nevada is undeveloped and the magnesite is not high grade.

#### 2. NATURE.

The mineral magnesite is a naturally occurring form of magnesium carbonate, MgCO<sub>3</sub>. It appears in two modifications.

**AMORPHOUS.**—This form is hard, compact, often concretionary, and probably is a hardened precipitate. The fracture is conchoidal, having the appearance and color of unglazed porcelain. Amorphous magnesite is generally the result of alteration of serpentine or similar high magnesian rocks and is commonly found in fissures or veins associated with the rocks from which it was derived. The deposits of Greece and California are examples of this class.

**CRYSTALLINE.**—The chief crystalline magnesite deposits are in Austria, Czechoslovakia, Canada, and the State of Washington. This modification probably was a replacement of lenses of dolomite produced by magnesian solutions. It occurs in masses along with limestone, dolomite, or associated sediments which have been metamorphosed. The structure is coarsely crystalline, and the color is white, pink, red, gray, or black.

### 3. IMPURITIES.

Magnesite is often very pure, containing only small amounts of silica, alumina, iron oxide, and lime. Lower grades contain admixtures of lime, clay, oxides of iron, serpentine, or some form of free silica. Manganese is found in some deposits in sufficient quantity to affect the color of the calcined magnesite.

## IV. CAUSTIC MAGNESIA.

Two types of kilns are in common use for calcining magnesite, the vertical stack kiln and the rotary kiln. The former type may be fired with wood, coal, coke, oil, or gas; whereas the rotary kiln is restricted to oil, gas, or powdered coal. The calcining operation consists of heating the sized magnesite until nearly all the carbon dioxide has been driven off, and, in certain cases, of further heating. Depending on the properties desired in the resulting magnesium oxide, a calcined magnesite falls into one of two general classes, namely, dead burnt magnesite and caustic magnesia. The properties of these two classes are very different and, furthermore, the properties often vary greatly within each class.

Dead burnt magnesite is produced by heating the magnesite sufficiently to change the amorphous magnesium oxide, which is first formed, into the dense crystalline state as found in nature and known as periclase. The temperature required to form periclase is lowered by the presence of iron, and therefore in preparing dead burnt magnesite either a magnesite containing about the

desired amount of iron is selected or iron oxide is added to a magnesite containing less of this impurity. Dead burnt magnesite is an excellent refractory material under certain conditions and is used extensively in lining furnaces for making basic open-hearth steel, in copper converters, reverberatories, and in furnaces for refining lead. It is not plastic and reacts only very slowly with water or magnesium chloride.

On the other hand, if magnesite is heated only sufficiently to drive off the greater part of the carbon dioxide, the product will be amorphous, of relatively low specific gravity, and if treated with water or a number of salt solutions becomes plastic and sets rapidly into a hard mass. If the temperature of calcination is increased, the product will be denser and less active chemically. Pure magnesium carbonate will lose all its carbon dioxide at approximately  $510^{\circ}\text{C}.$ <sup>9</sup> Commercially, the temperature employed in calcining magnesite for use as a cement is much higher than this and probably varies from 700 to  $1,200^{\circ}\text{C}.$  The very low calcined product, if recently calcined, is too quick setting, without a retarder, for use as a structural cement.

The other extreme, represented by a highly calcined magnesite, will not be sufficiently active and will give too slow set. Properties other than the rate of setting are affected by the manner in which the magnesia has been calcined. Therefore the manufacturer should calcine the magnesite to a degree which will result in a product having satisfactory properties. It is misleading to say that a satisfactory product may be obtained by burning at some fixed temperature, as the temperature required in the kiln will vary with the nature of the magnesite, impurities, duration of the calcining operation, size of particles, and surface of magnesite exposed to the sources of heat. To determine the most efficient conditions which will give the desired product is then a problem for the individual plant.

If exposed to the atmosphere, plastic magnesia will take up water and carbon dioxide at a rate depending upon the conditions of exposure and the degree of calcination. This absorption may be very marked in the case of a lightly calcined magnesia, and the behavior of the cement will be affected greatly.

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<sup>9</sup> U. S. Geological Survey Bulletin No. 355, p. 10.

## V. USES OF CAUSTIC MAGNESIA CEMENT.

## 1. FLOORING.

Probably the earliest use made of this cement was in imitation stone or building blocks, where it proved unsuccessful, as the blocks were not durable under exposure to the weather. However, it was soon found that if mixed with various ingredients the material had desirable properties for interior construction, particularly as flooring. It was used extensively in this way in France and Germany before the trade was introduced into this country.

The properties of this so-called composition flooring largely depend upon the ingredients which are mixed with the cement. The floors may vary from a hard, dense type to one comparatively soft and resilient. Many different materials have been used in flooring mixtures to bring out certain of these qualities, as sand, ground silica, sawdust, and other fibrous vegetable matter, asbestos, leather scrap, ground cork, talc, clay, kieselguhr, and pigments. Many different formulas are used, even though the type of flooring desired may be identical. Some are patented and others are, in a way, secret. A general idea of the more common resilient type flooring mixtures is expressed by the formulas given below :

Ingredients.	Bottom coat.	Top coat.	Ingredients.	Bottom coat.	Top coat.
	Per cent by weight.	Per cent by weight.		Per cent by weight.	Per cent by weight.
Caustic magnesia.....	35.0	45	Wood flour.....		10
Sand.....	7.5		Asbestos fiber.....		5
Ground silica.....	25.0	20	Clay, talc, or Sil-o-cel.....	7.5	10
Sawdust.....	25.0		Pigment.....		10

It should be understood that these formulæ are not to be followed exactly for general use. The quality of the magnesite, the physical properties of the inert materials, and the type of floor desired will make modifications necessary in order to obtain the best results. A great deal of experience and some testing of the ingredients is a prerequisite to the proportioning of flooring mixtures.

The ground silica or other fine inert material serves to dilute the magnesia, which to a degree is essential in guarding against large changes in volume typical of the oxychloride cement if used alone. The fibrous materials, especially sawdust and wood flour, and probably Sil-o-cel, produce resiliency; clay and talc act as

diluents but are used chiefly to make troweling easier and to add to the smoothness of the surface. Asbestos fibers also add to the working qualities of the wet mixture.

The dry ingredients should be thoroughly mixed and when ready to use should be made plastic with a solution of magnesium chloride (22° B.). The mixture may then be placed in much the same manner as Portland cement floors are laid. The floor is given a final troweling after it has stiffened considerably but before it has become nonplastic. This operation produces a more compact and smooth surface, making it more resistant to wear and more suitable for polishing or waxing. One without experience should not attempt the laying of composition flooring unless personally supervised by an experienced operator.

Composition floors are laid in one or two coats, each usually one-fourth or three-eighths inch in thickness. Often, if two coats are used, as over wood, reinforcing in the form of wire netting or mesh is first fastened to the floor. There is no uniform practice in the use of reinforcing or in the use of the bottom coat.

The desirable qualities of composition flooring, some of which have already been suggested, are as follows:

- (1) Adaptability for covering old floors.
- (2) Variety of colors which may be obtained by the use of various pigments.
- (3) Resiliency.
- (4) Sanitary advantages owing to the absence of a large number of cracks or joints, and low absorption.
- (5) It is fire resistant. (It can not be considered fireproof as disintegration occurs at moderately low temperatures.)
- (6) It can be laid and is ready for use in a comparatively short time.

## 2. STUCCO.

The application of caustic magnesia to the exterior stucco trade in this country is of a comparatively recent date. Probably the oldest stucco of this kind was placed 10 or 12 years ago. Although failures with reference to durability occasionally occur, this type of stucco has gained considerable popularity in many localities.

It has a number of features which are very attractive. Owing to the low freezing point of the magnesium chloride solution which is used for wetting the dry mixture, it can be placed during cold weather with very little if any danger of freezing. There is not the tendency to craze or form map cracks upon setting as in

Portland cement stucco. On account of the very low amount of cementing material used in the stucco mixture and consequently the great amount of inert material, this type of stucco seems to show very slight volume changes produced by humidity changes in the atmosphere and by the process of setting. This is one of the reasons for the small amount of cracking usually noted and the absence of crazing. The tensile and compressive strength of such lean mixtures is high compared with other types of stuccos which are made of mixtures with higher percentages of cementing materials.

Caustic magnesia stucco usually consists of two coats, scratch and finish. If a dash is used it is embedded in the finish coat by throwing against the soft mixture on the wall with the hand or a paddle. White sand is generally used in the finish coat for the sake of appearance.

Below is an example of a finish coat for stucco:

	Per cent by weight.
Caustic magnesia.....	15
Asbestos fiber.....	3
Ground silica.....	15
Sand.....	67

The under coat might contain less magnesia and some cork. As in flooring compositions an ordinary colored sand could be used. The best results may be had by intelligently modifying the above proportions according to the properties of the plastic magnesia and inert materials.

The dry mixtures are gaged with a magnesium chloride solution (22° B.) to a good workable consistency and applied to the wall with a trowel. The scratch coat should be used to even the surface and cover the high places to a depth of about one-fourth inch. As soon as this has hardened sufficiently to support the finish coat without sagging, or at anytime thereafter, the finish coat is applied to a depth of about one-fourth inch.

If the surface to be covered is dry, it is customary to wet this with the magnesium chloride solution or a thin mixture of caustic magnesia and magnesium chloride just previous to the application of the stucco coat to prevent excessive absorption of the solution from the mixture.

### 3. SHIP DECKING.

Another important product of caustic magnesia is deck covering for ships. The practice in this trade is very different from that in the flooring trade owing to the peculiar requirement which the

product should fulfill. In covering steel decks, it is necessary to lay the mixture 3 or 4 inches thick in order to produce a plane surface over irregularities such as laps or straps at the joints. It is obvious that this material should be as light as possible, and to effect this quality, it is customary to use as much light weight aggregate as the other requirements will allow. Coarse sawdust answers very well as the bulky part of the mixture, as a finished surface is not often required. Some kind of a covering, such as carpet or tile is usually placed entirely over the composition decking. Of course a finished surface, if desired, may be obtained by coating the decking with a magnesia flooring mixture.

As the composition decking does not bond itself very firmly to the steel plates, it is necessary to use some form of anchorage. One method is to weld a steel strap that has been bent into the shape of a section of Z bar to the steel deck at regular intervals. As a means of preventing corrosion of the steel, it is often coated with bituminous paint.

## VI. SPECIFICATIONS.

Until recently no attempt has been made to develop standard tests or requirements for caustic magnesia. Certain purchasers specified that shipments must meet certain requirements, as a minimum and maximum for the carbon dioxide and a maximum for lime, but the limits stated varied considerably. Furthermore, no physical requirements of any kind were ever used, chemical requirements based upon a partial or complete chemical analysis being the sole means used in determining the usability of purchases. As a result of the lack of such physical requirements as minimum strength, low coefficient of expansion, fine grinding, and accelerated aging tests, a variable product was placed upon the market and improperly used. This, combined with lack of knowledge of the quality of the aggregates at hand and improper workmanship, caused certain unsatisfactory results.

With the shutting off of importations during the late war, the calciners in this country were gradually forced to a study of their products, while at the same time the users began to study and test the domestic product which seemed to give results different from the previously used imported oxide. The consequence has been a greater development in a few years of a knowledge of the qualities which a caustic magnesia should have than had taken place since it was first produced as a cementing agent.

A committee representing an organization of producers on the Pacific coast, of manufacturers of caustic magnesia products throughout the United States, of one of the larger domestic producers of magnesium chloride, and two of the Federal bureaus has been engaged lately in preparing a set of specifications and methods of tests for these products.

The chemical analyses or any chemical requirements have been entirely omitted on account of their total inadequacy in defining a satisfactory magnesia. The physical requirements are based upon color, fineness, set, transverse and possibly tensile strength, and linear change in volume. Definite values for these have not been finally determined upon, although the methods of tests have been practically decided upon.

A great deal of discussion has arisen over the desirability of a color standard. As a general rule, the imported product will have a whiter color than the domestic, and consequently the user, on account of his longer acquaintance with the imported oxide, is inclined to prefer white to a slightly tinted magnesia, notwithstanding the fact that in setting and aging the latter will bleach to as white a tint as the former. A suggested compromise has been the requirement that the delivery shall match or be lighter than the one of a series of color standards indicated in the purchase proposal.

Fineness has been a matter to which but little attention has been paid in purchases up to the present. As, however, the speed and the degree of the reaction between the oxide and the chloride depends so much upon this factor, a rather fine product as measured by previous deliveries is desired. Hence a residue of 3 per cent on a No. 100 sieve and 25 per cent on a No. 200 sieve is thought to give a superior product, and at the same time it is a requirement which will not inflict a too great hardship on the manufacturer.

While a very rapid set may give a product of low strength or one with a high early strength but little or no gain in strength with age, and a very slow set a product of low strength, in itself the time of set is more of a matter of ease and economy in usage. Hence neither the initial nor the final set should be so rapid as to entail undue speed upon workmen nor the final set so slow as to make final troweling and finishing a matter of uncertainty or inconvenience. Hence an initial set of not less than one hour and a final set of eight hours is suggested. Both determinations are to be made with the Gilmore needles and upon a mortar

composed of the magnesite in question, fine silica, and standard sand.

The use of such a mortar instead of neat cement for all test purposes has been found to be essential. The results of testing the cement in the neat state are in no way indicative of what will be obtained in practice when the magnesia is used in the form of a rather lean mortar. The suggested proportions for the test mortar are 1 part magnesia, 2 parts fine silica, and 5 parts standard Ottawa sand by weight. The fine silica is white sand or quartz, ground so that 95 per cent will pass a No. 100 sieve and 75 to 85 per cent pass a No. 200 sieve.

In view of the fact that caustic magnesia is used in mortar applied in thin coats and subjected mostly to flexural stresses, it was felt that a strength test should be confined to the determination of the modulus of rupture (transverse strength) of a bar of a cross section of  $\frac{1}{2}$  by 2 inches. The suggested bars should be of such a length as to give a distance between supports of 10 or 20 inches. As a suitable machine for such tests is not in common use or on the market, the tensile strength of a briquette of the form used in testing Portland cement has also been suggested. In either case the test specimens are to be broken at the end of 24 hours, and seven days after storage in the air of the laboratory. A good caustic magnesia when so tested will give a transverse strength of 500 pounds per square inch and 1,000 pounds per square inch and a tensile strength of 250 pounds per square inch and 350 pounds per square inch at the end of 24 hours and seven days, respectively.

One of the most common causes of the failure of caustic magnesia cement products is due to the excessive contraction or expansion of the cement; hence the necessity of a requirement in a specification limiting these changes. It has been suggested that the linear change in volume of the bars for transverse tests to be broken at seven days be determined by a suitable micrometer or gage (as the Berry or Olsen strain gage) at final set, 24 hours and seven days after final set. With proper reference points and an optical bench the measurements may be started immediately after placing the reference points. The suggested limits of a contraction not to exceed 0.15 per cent or an expansion not to exceed 0.30 per cent of the original length may seem to be excessive. However, the mortars are always used in thin layers upon a base which is stable so far as volume changes are concerned and which acts as a reinforcing. In certain cases,

as in flooring on old wooden floors, reinforcing is actually used. Consequently the volume change in practice is not nearly as marked as that obtained in the test specimen. In some work at the bureau involving tests of samples of commercial composition flooring the linear change in volume was measured on bars of the flooring of the type indicated above and on bars of the flooring laid upon a bar of aged Portland cement mortar, such as might be used to cover concrete slabs and in turn be covered with composition flooring. Simultaneous observations made on the two sets of bars show that the volume change in the latter type of bar will be but from 10 to 30 per cent of that of the former type.

The above indicates the factors which are being considered in the preparation of specifications and also that might be used in the meantime as tests by those wishing to secure some idea of the quality of caustic magnesia in which they are interested.

WASHINGTON, July 25, 1922.



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DEPARTMENT OF COMMERCE

BUREAU OF STANDARDS

S. W. STRATTON, Director

U.S.

CIRCULAR OF THE BUREAU OF STANDARDS

*Cotton Duck Association* No. 136

[September 22, 1922]

SPECIFICATION FOR NUMBERED COTTON DUCK FOR  
GOVERNMENT AND COMMERCIAL USE

ABSTRACT.

This specification was prepared by the Cotton Duck Association, the technical committee on textiles of the Federal Specifications Board, and the Bureau of Standards, under the supervision of the textile section of the Bureau of Standards. The specification includes weave, width, weight, count, ply, and breaking strength; also an expression as to what constitutes good delivery. This specification was drawn up for Government and commercial use.

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1. INTRODUCTION.

This specification was drawn up by the Cotton Duck Association and several of the large Government departments. The results of tests made at the Bureau of Standards were used to establish most of the tolerances and figures.

2. MATERIAL.

The duck shall be made of cotton thoroughly cleaned and free from waste. It shall be evenly woven without sizing, and shall be free from an excessive number of avoidable imperfections of manufacture.

**3. WEAVE.**

The weave shall be plain.

**4. WIDTH.**

The average width shall be as specified with the following tolerances:

	Inch.
Widths up to and including 36 inches.....	- $\frac{1}{4}$ to + $\frac{1}{4}$
37 to 60 inches.....	- $\frac{1}{4}$ to + $\frac{3}{8}$
61 to 80 inches.....	- $\frac{3}{8}$ to + $\frac{3}{8}$
81 to 120 inches.....	- $\frac{3}{8}$ to + $\frac{3}{8}$

**5. WEIGHT.**

The requirements for weight shall be as given in the table below with a tolerance of  $2\frac{1}{2}$  per cent, plus or minus.

**6. CONSTRUCTION AND COUNT.**

The number of ply, and the count (or number of threads per inch, warp and filling) shall not be uniformly less than shown in the table below. They may be exceeded in the discretion of the manufacturer. The allowable variation from the manufacturers' standard shall not exceed, within a bolt or roll, for the WARP:

- $\pm 1\frac{1}{2}$  threads in fabrics counting not over 40 threads per inch;
- $\pm 2$  threads in fabrics counting over 40 threads per inch;

and for the FILLING:

- $\pm 1$  thread in fabrics counting not over 25 threads per inch;
- $\pm 1\frac{1}{2}$  threads in fabrics counting from  $25\frac{1}{2}$  to 32 threads per inch;
- $\pm 2$  threads in fabrics counting over 32 threads per inch.

The count shall be determined by ascertaining the number of threads in 3 inches, taken consecutively, and reducing to terms of 1 inch. The warp count shall not be taken at less than 8 inches from either selvage for goods 26 inches or more in width; for goods under 26 inches, it shall not be taken nearer the selvage than one-fourth of the entire width of the fabric.

**7. METHOD OF TESTING.**

From each delivery of 1,000 yards or fraction thereof a sample of not more than 2 linear yards shall be cut from any part of at least 2 rolls for test purposes.

Tests may be made under prevailing atmospheric conditions, except in the settlement of disputes concerning weight and strength. Such tests shall then be made upon material having

normal moisture content, obtained by exposure for at least 4 hours to an atmosphere of 65 per cent relative humidity at 70° F. temperature.

All tests for breaking strength shall be made on an approved type of inclination balance-breaking machine. The maximum capacity of the machine shall be 800 pounds.

The 1 by 1 by 3 inches grab method of testing shall be used, defined as follows: The lower half of each pair of jaws shall be 2 inches or more in width and the upper half shall be 1 inch in width. Jaws shall be planed smooth and flat with edges slightly rounded to prevent cutting. The initial length of the test pieces between the jaws of the testing machine shall be 3 inches, and the pulling jaw shall travel at a uniform rate of 12 inches per minute. Six test pieces, 6 inches long by 4 inches wide, shall be cut, 3 in the direction of the warp and 3 in the direction of the filling, respectively. Care shall be taken that no two test pieces include the same threads. The average result of the tests shall be recorded separately for warp and filling. No sample for testing shall be taken at less than 8 inches from either selvage for goods 26 inches or more in width or for goods under 26 inches at less than one-fourth of the entire width of the fabric. If the width of the goods does not admit of cutting pieces as stated above, they shall be taken as near the center as possible.

In the case of a break evidently below the general average for the fabric, a second test on the same threads shall be made, and this test shall then be used in obtaining the average result.

### 8. CAUSES FOR REJECTION.

In the event of a dispute in regard to width, the average width shall be determined by measuring in not less than 5 places, about equally distant, throughout the length of the bolt or roll. In no place shall the variation in width be more than  $\frac{1}{8}$  inch greater than the tolerance for average width specified in paragraph entitled "Width."

In the event of a dispute in regard to weight, the weight per square yard shall be determined from the nominal width, the invoiced yardage (verified when necessary), and the actual weight of the entire bolt or roll. The results of tests on 1 or 2 yards for width and weight shall not be used alone as a basis for rejection.

No rolls or bolts running less than 10 per cent under the strength specified shall be rejected, provided the delivery in question shall average up to specifications.

No rolls or bolts shall be rejected the combined strength of the warp and filling of which shall be equal to the combined strength specified in the table below, provided neither element is more than 10 per cent under the requirements applying to that element.

### 9. DEFINITION.

The terms "bolts" or "rolls" as used above are hereby defined as meaning continuous lengths averaging from 100 to 110 yards, but a roll or bolt of not less than 85 yards will constitute a good commercial delivery.

TABLE 1.—Construction, Weight, and Strength.

No. of duck.	Weight.		Width.	Dis- tance of selvage strips from edge.	Minimum ply.		Minimum thread count per linear inch.		Breaking strength 1 by 1 by 3 inches grab.	
	Per lin- ear yard 22 inch- es wide.	Per square yard.			Warp.	Filling.	Warp.	Filling.	Warp.	Filling.
<b>Hard texture:</b>	<b>Ounces.</b>	<b>Ounces.</b>	<b>Inches.</b>	<b>Inches.</b>					<b>Pounds.</b>	<b>Pounds.</b>
2/0 .....	20	32.72	As specified	2	5	7	26	18	465	435
1/0 .....	19	31.09	do.	2	5	6	26	18	450	405
1 .....	18	29.45	do.	1 3/4	5	5	26	19	440	370
2 .....	17	27.82	do.	1 3/4	5	5	27	21	420	345
3 .....	16	26.18	do.	1 3/4	4	5	29	21	390	330
4 .....	15	24.54	do.	1 3/4	4	4	29	22	375	300
5 .....	14	22.90	do.	1 3/4	3	4	34	24	345	285
6 .....	13	21.27	do.	1 3/4	3	3	34	26	335	250
7 .....	12	19.63	do.	1 3/4	3	3	35	22	300	240
8 .....	11	18.00	do.	1 3/4	3	3	33	23	285	210
9 .....	10	16.36	do.	1	3	3	38	25	255	195
10 .....	9	14.72	do.	1	3	3	44	26	245	185
11 .....	8	13.08	do.	1	3	2	44	32	235	125
12 .....	7	11.45	do.	1	2	2	48	34	195	120
					3	2	40	34		
<b>Medium texture:</b>										
2/0 .....	20	32.72	do.	2	5	8	26	16	450	405
1/0 .....	19	31.09	do.	2	5	6	26	16	435	390
1 .....	18	29.45	do.	1 3/4	5	5	26	17	425	345
2 .....	17	27.82	do.	1 3/4	5	5	26	16	410	320
3 .....	16	26.18	do.	1 3/4	4	5	26	17	370	315
4 .....	15	24.54	do.	1 3/4	4	4	28	19	350	290
5 .....	14	22.90	do.	1 3/4	3	4	28	20	315	285
6 .....	13	21.27	do.	1 3/4	3	3	34	20	305	250

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Specification,  
No. 53.

**DEPARTMENT OF COMMERCE.**

**BUREAU OF STANDARDS.**

**George K. Burgess, Director.**

**CIRCULAR OF THE BUREAU OF STANDARDS, NO. 136.**

(2d edition. Jan. 12, 1924.)

**UNITED STATES GOVERNMENT SPECIFICATION FOR  
NUMBERED COTTON DUCK.<sup>1</sup>**

**FEDERAL SPECIFICATIONS BOARD.**

**STANDARD SPECIFICATION NO. 53.**

This specification was officially adopted by the Federal Specifications Board on February 1, 1923, for the use of the Departments and Independent Establishments of the Government in the purchase of numbered cotton duck.

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This specification was drawn up by the Cotton Duck Association and several of the large Government departments. The results of tests made at the Bureau of Standards were used to establish most of the tolerances and figures.

**2. MATERIAL.**

The duck shall be made of cotton thoroughly cleaned and free from waste. It shall be evenly woven without sizing, and shall be free from an excessive number of avoidable imperfections of manufacture.

<sup>1</sup> This specification was adopted by the Cotton Duck Association.

**3. WEAVE.**

The weave shall be plain.

**4. WIDTH.**

The average width shall be as specified with the following tolerances:

Widths up to and including—	Inch.
36 inches.....	$-\frac{1}{4}$ to $+\frac{1}{4}$
37 to 60 inches.....	$-\frac{1}{4}$ to $+\frac{3}{8}$
61 to 80 inches.....	$-\frac{3}{8}$ to $+\frac{3}{8}$
81 to 120 inches.....	$-\frac{3}{8}$ to $+\frac{3}{4}$

**5. WEIGHT.**

The requirements for weight shall be as given in the table below with a tolerance of  $2\frac{1}{2}$  per cent, plus or minus.

**6. CONSTRUCTION AND COUNT.**

The number of ply and the count (or number of threads per inch, warp and filling) shall not be uniformly less than shown in the table below. They may be exceeded in the discretion of the manufacturer. The allowable variation from the manufacturers' standard count shall not exceed, within a bolt or roll, for the **WARP**:

- $\pm 1\frac{1}{2}$  threads in fabrics counting not over 40 threads per inch;
- $\pm 2$  threads in fabrics counting over 40 threads per inch;

and for the **FILLING**:

- $\pm 1$  thread in fabrics counting not over 25 threads per inch;
- $\pm 1\frac{1}{2}$  threads in fabrics counting from  $25\frac{1}{2}$  to 32 threads per inch;
- $\pm 2$  threads in fabrics counting over 32 threads per inch.

The count shall be determined by ascertaining the number of threads in 3 inches, taken consecutively, and reducing to terms of 1 inch. The warp count shall not be taken at less than 8 inches from either selvage for goods 26 inches or more in width; for goods under 26 inches it shall not be taken nearer the selvage than one-fourth of the entire width of the fabric.

**7. METHOD OF TESTING.**

From each delivery of 1,000 yards or fraction thereof a sample of not more than 2 linear yards shall be cut from any part of at least two rolls for test purposes.

Tests may be made under prevailing atmospheric conditions, except in the settlement of disputes concerning weight and strength. Such tests shall then be made upon material having normal moisture content, obtained by exposure for at least four hours

to an atmosphere of 65 per cent relative humidity at 70° F. temperature.

All tests for breaking strength shall be made on an approved type of inclination balance breaking machine. The maximum capacity of the machine shall be 800 pounds.

The 1 by 1 by 3 inches grab method of testing shall be used, defined as follows: The lower half of each pair of jaws shall be 2 inches or more in width and the upper half shall be 1 inch in width. Jaws shall be planed smooth and flat with edges slightly rounded to prevent cutting. The initial length of the test pieces between the jaws of the testing machine shall be 3 inches, and the pulling jaw shall travel at a uniform rate of 12 inches per minute. Six test pieces, 6 inches long by 4 inches wide, shall be cut, three in the direction of the warp and three in the direction of the filling, respectively. Care shall be taken that no two test pieces include the same threads. The average result of the tests shall be recorded separately for warp and filling. No sample for testing shall be taken at less than 8 inches from either selvage for goods 26 inches or more in width, or for goods under 26 inches at less than one-fourth of the entire width of the fabric. If the width of the goods does not admit of cutting pieces as stated above, they shall be taken as near the center as possible.

In the case of a break evidently below the general average for the fabric, a second test on the same threads shall be made and this test shall then be used in obtaining the average result.

In the event of a dispute regarding measurements, the material shall be placed under sufficient tension to make it lie flat upon a table, or other plane surface, and exposed to an atmosphere of 65 per cent relative humidity at 70° F. temperature, and when measured under these conditions the yardage delivered shall be not less than the invoiced yardage.

#### 8. CAUSES FOR REJECTION.

In the event of a dispute in regard to width, the average width shall be determined by measuring in not less than five places about equally distant, throughout the length of the bolt or roll. In no place shall the variation in width be more than one-eighth inch greater than the tolerance for average width specified in paragraph entitled "Width."

In the event of a dispute in regard to weight, the weight per square yard shall be determined from the nominal width, the invoiced yardage (verified when necessary), and the actual weight of

the entire bolt or roll. The results of tests on 1 or 2 yards for width and weight shall not be used alone as a basis for rejection.

No rolls or bolts running less than 10 per cent under the strength specified shall be rejected, provided the delivery in question shall average up to specifications.

No rolls or bolts shall be rejected, the combined strength of the warp and filling of which shall be equal to the combined strength specified in the table below, provided neither element is more than 10 per cent under the requirements applying to that element.

#### 9. DEFINITION.

The terms "bolts" or "rolls" as used above are hereby defined as meaning continuous lengths averaging from 100 to 110 yards, but a roll or bolt of not less than 85 yards will constitute a good commercial delivery.

TABLE 1.—Construction, Weight, and Strength.

No. of duck.	Weight.		Width.	Dis- tance of selvage stripe from edge.	Minimum ply.		Minimum thread count per linear inch.		Breaking strength 1 by 1 by 3 inches grab.	
	Per lin- ear yard 22 in- ches wide.	Per square yard.			Warp.	Filling.	Warp.	Filling.	Warp.	Filling.
<b>Hard texture:</b>	<b>Ounces.</b>	<b>Ounces.</b>	<b>Inches.</b>	<b>Inches.</b>					<b>Pounds.</b>	<b>Pounds.</b>
2/0.....	20	32.72	As specified	2	5	7	26	18	465	435
1/0.....	19	31.09	do.....	2	5	6	26	18	450	405
1.....	18	29.45	do.....	1½	5	5	26	19	440	370
2.....	17	27.82	do.....	1½	5	5	27	21	420	345
3.....	16	26.18	do.....	1½	4	5	29	21	390	330
4.....	15	24.54	do.....	1½	4	4	29	22	375	300
5.....	14	22.90	do.....	1½	3	4	34	24	345	285
6.....	13	21.27	do.....	1½	3	3	34	26	335	250
7.....	12	19.63	do.....	1½	3	3	35	22	300	240
8.....	11	18.00	do.....	1½	3	3	33	23	285	210
9.....	10	16.36	do.....	1	3	3	38	25	255	195
10.....	9	14.72	do.....	1	3	3	44	26	245	160
11.....	8	13.08	do.....	1	3	2	44	32	235	125
12.....	7	11.45	do.....	1	2	2	48	34	195	120
					3	2	40	34		
<b>Medium tex- ture:</b>										
2/0.....	20	32.72	do.....	2	5	8	26	16	450	405
1/0.....	19	31.09	do.....	2	5	6	26	16	435	380
1.....	18	29.45	do.....	1½	5	5	26	17	425	345
2.....	17	27.82	do.....	1½	5	5	26	16	410	320
3.....	16	26.18	do.....	1½	4	5	26	17	370	315
4.....	15	24.54	do.....	1½	4	4	28	19	350	290
5.....	14	22.90	do.....	1½	3	4	28	20	315	285
6.....	13	21.27	do.....	1½	3	3	34	20	305	250

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DEPARTMENT OF COMMERCE

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# CIRCULAR

OF THE

U. S.  
" **BUREAU OF STANDARDS**

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No. 137

**AUXILIARY CONDENSERS AND LOADING  
COIL USED WITH SIMPLE HOMEMADE  
RADIO RECEIVING OUTFITS**

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FEBRUARY 23, 1923



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**WASHINGTON  
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1923**



# AUXILIARY CONDENSERS AND LOADING COIL USED WITH SIMPLE HOMEMADE RADIO RECEIVING OUTFITS.

## ABSTRACT.

This is the fourth circular in a series of descriptions of very simple radio receiving outfits. In Circular No. 120 a single-circuit crystal-detector receiving set was described, and in Circular No. 121 a two-circuit crystal-detector set was described. The operation of either set can be improved by the use of a very simple and cheap condenser connected across the telephone receivers and a similar one connected in series with the antenna. Longer waves can be received by the use of a very simple type of loading coil. The coil is particularly useful in connection with the single-circuit receiving set.

The auxiliary condenser, which is used in series with the antenna, and the loading coil may also be used when the crystal detector is replaced by an electron-tube detector unit (as described in Circular No. 133) or when an amplifier (to be described in a later circular) is added to the receiving set.

The condenser used in series with the antenna makes it convenient to tune to wave lengths less than 300 m. The condenser used across the telephone receivers increases the intensity of signals which are received from some radio stations. The loading coil enables the equipment to respond to wave lengths above 600 m up to about 3,000 m. Time signals from high-power stations can thus be received. The parts for the auxiliary condensers cost about 80 cents, and the parts for the loading coil cost about \$3.

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## I. INTRODUCTION.

This circular<sup>1</sup> describes auxiliary equipment for use with the simple radio receiving outfits described in Circulars Nos. 120 and 121. Both the auxiliary condensers and the loading coil may be

<sup>1</sup> This is the fourth of a series of circulars describing very simple radio receiving equipments, which were originally prepared for use by the Boys' and Girls' Radio Clubs of the States Relations Service, Department of Agriculture. The previous circulars of the series are: Bureau of Standards Circular No. 120, Construction and Operation of a Simple Homemade Radio Receiving Outfit; Circular No. 121, Construction and Operation of a Two-Circuit Radio Receiving Equipment with Crystal Detector; Circular No. 133, Description and Operation of an Electron-Tube Detector Unit for Simple Radio Receiving Outfits. These circulars are obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. The price of Circular No. 120 is 5 cents; Circular No. 121, 5 cents; Circular No. 133, 10 cents.

Persons desiring an elementary book covering radio principles may refer to The Principles Underlying Radio Communication, Signal Corps Radio Communication Pamphlet No. 40. This is a book of over 600 pages, and contains over 300 illustrations. A copy may be purchased for \$1 from the Superintendent of Documents, Government Printing Office, Washington, D. C.

used with the simple sets as described in those circulars. The loading coil and the condenser, which is connected in series with the antenna, may also be used when the crystal detector is replaced by an electron-tube detector unit (as described in Circular No. 133), or when an amplifier (to be described in a later circular) is added to the receiving set.

Three things are described herein—two simple condensers and a loading coil—the condensers are so-called fixed condensers; that is, the capacity is not variable. One of the fixed condensers, which is connected in series with the antenna, will be called in this circular the “series-antenna” condenser. The other fixed condenser, which is connected across the terminals of the telephone receivers, will be called the “telephone-shunt” condenser.

The effect of the series-antenna condenser is to enable the receiving equipment to give signals of somewhat greater intensity when tuned to wave frequencies above 1,000 kilocycles per second (that is, wave lengths of 300 m or less). It will thus be seen that the effect of this condenser is just the opposite of the effect obtained by a greater number of turns of wire on a tuning coil, which, it will be remembered, permits the receiving equipment to respond to lower wave frequencies (longer wave lengths).

The effect of the telephone-shunt condenser is to increase the intensity of some radio signals to which the receiving set may be tuned. In most cases the use of this condenser has no effect upon the intensity of signals which are received from a radio telephone transmitting station, but will increase the intensity of radio signals which are received from most spark transmitting stations.

The loading coil is primarily for use in conjunction with the single-circuit radio receiving set described in Circular No. 120. The experimenter who is interested in using it in connection with the two-circuit set described in Circular No. 121 is referred to the paragraph entitled “Use with two-circuit set,” near end of this circular. The purpose of the loading coil is to enable the receiving equipment to respond to wave frequencies between 100 and 500 kilocycles per second (that is, wave lengths between 3,000 and 600 m). In other words, the loading coil increases the wave frequency (wave length) range of the receiving set. The receiving set described in Bureau of Standards Circular No. 120 has a wave frequency (wave length) range of between 500 and 1,500 kilocycles per second (wave lengths between 600 and 200 m).

The use of the loading coil will increase the receiving distance of the equipment, because many stations using the lower wave frequencies (longer wave lengths) use a high-power radio transmitting set. For example, the station NAA at Arlington, Va., which transmits time signals, uses a wave frequency of about 113 kilocycles per second (2,650 m wave length) and uses sufficient power to be heard a distance of about 200 miles when the loading coil described in this circular is used with the receiving equipment described in Circular No. 120 or its equivalent. At night this distance may be considerably increased. The cost of the parts for the two condensers is about 80 cents, and for the loading coil is about \$3.

This publication describes simple apparatus of satisfactory performance without reference to the possible existence of any patents which might cover parts of the apparatus. Apparatus in general similar to that described can be purchased from responsible manufacturers whose announcements can be found in current radio periodicals.

## II. DESCRIPTION OF SERIES-ANTENNA CONDENSER.

The series-antenna condenser is shown in detail in Figures 1A and 1B. Two thin strips of metal (*C* and *E*) 1 inch wide and 3 inches long are used with three sheets of insulating material (*B*, *D*, and *F*) 1½ inches wide by 3 inches long. The metal strips may be thin copper, brass, or aluminum. Each of the three sheets of insulating material is made up of two pieces of heavy white writing paper which are separately dipped in clean, melted paraffin. Each pair of sheets is then pressed together by means of a warm iron, and when cold the strip is cut out to the required size. A sheet of clear mica, having about the same thickness as the two sheets of writing paper mentioned above, may also be used for the insulating material. Two blocks (*G*=2½ by 3 by ½ inches, *A*=3 by 3½ by ½ inches) are cut out preferably from hardwood. Two screws pass through holes *H* and *J* in the upper cap block *G*, which is placed over the base block *A*, so that the edges of the two blocks are even on three sides. (See Fig. 1A.) The holes for the screws *H* and *J* are ⅜ inch from the sides of the cap block *G* and equally distant from the ends. Having located the correct position of the cap block *G*, the screws in holes *H* and *J* are loosened and the cap block is removed from *A*, leaving two small holes *H'* and *J'* to locate the proper position of the blocks when the condenser is finally

assembled. The two screws *L* and *M* are located just far enough in from the front edge (see *A*, Figs. 1A and 1B) so that the block *A* may be screwed to the left end of the baseboard of the receiving set described in Circular No. 120 or to the primary coil support described in Circular No. 121. (See Figs. 2 and 3.)

The wooden blocks are of dry wood smoothed up with sandpaper and given a coat or two of varnish which will not absorb moisture, such as a spar varnish, or treated with paraffin, as described in Circular No. 120.

A sheet of the paraffined paper or mica *B* is placed on the base block *A*, between the holes *H'* and *J'*, so that its ends are even with ends of the base block. A thin metal strip *C* is placed in position so that it lies in the center of *B* and has its right end  $\frac{1}{2}$  inch

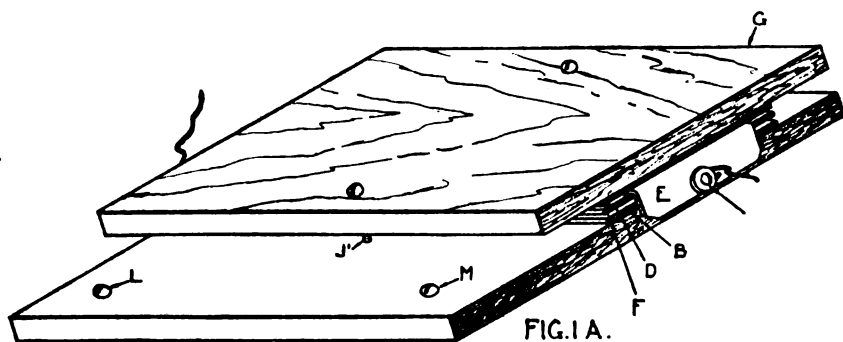


FIG. 1A.—Completed series-antenna condenser.

in from the edge of the base block and its left end projecting  $\frac{1}{2}$  inch over the opposite edge of the base block. (See Fig. 1B.)

Another sheet of paraffined paper *D* is placed on *C* directly above *B*. The second piece of thin metal *E* is placed on *D* above *C*, except that one end of the metal strip *E* extends  $\frac{1}{2}$  inch over the right edge of block *A* instead of the left, as did *C*. The third sheet of paraffined paper *F* is placed on *E* directly above *D* and *B*.

The alternate sheets of paraffined paper and thin metal are held carefully in position, and the cap block *G* is placed over them and screwed in position. The right end of the thin metal strip *E* is bent down, and a round-head brass screw *N* is passed through a hole *K* punched or drilled in the end of the metal strip. The projecting end of the strip *C* is not visible in Figure 1A, but it is bent and fastened in the same manner as *E*. The completed condenser resembles the sketch shown in Figure 1A.

(a) MOUNTING AND WIRING.—The condenser is mounted on either the single-circuit receiving set, described in Circular No. 120 or the two-circuit receiving set, described in Circular No. 121. Figure 2 shows the method of mounting the condenser on the

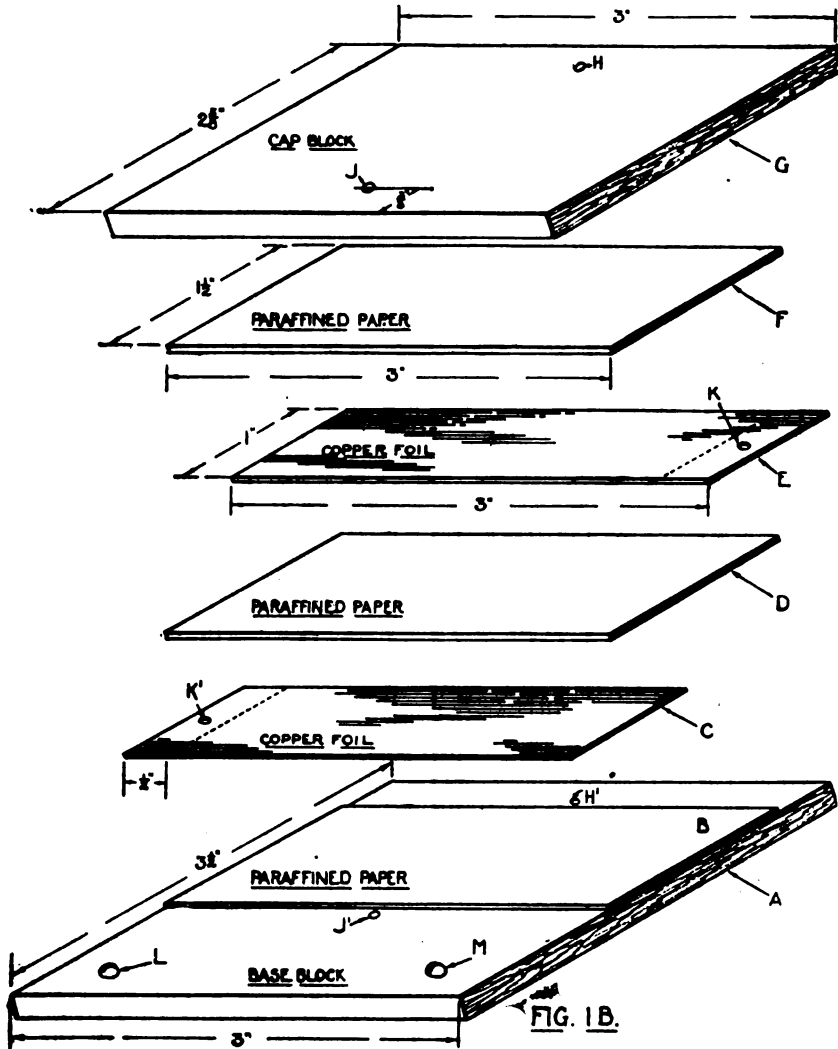


FIG. 1B.—Assembly of series-antenna condenser.

single-circuit receiving set. The condenser is fastened to the end of the baseboard by means of the screws *L* and *M*. A binding post *P* is added to the panel of the receiving set about 1 inch from the binding post marked "antenna," as shown in Figure 2. A wire is clamped under the condenser screw *N*, which passes

through the metal strip *E*, forming one terminal of the condenser. This wire is led to and connected to the back of the binding post marked "antenna" without disturbing any of the other wires which are already connected to this binding post. Another wire is connected to the terminal of the metal sheet *C* and led to the back of the binding post *P*.

In Circular No. 120 a short, stiff wire is shown attached to the "antenna" binding post and extending toward a similar wire attached to the "ground" binding post. The wire on the "an-

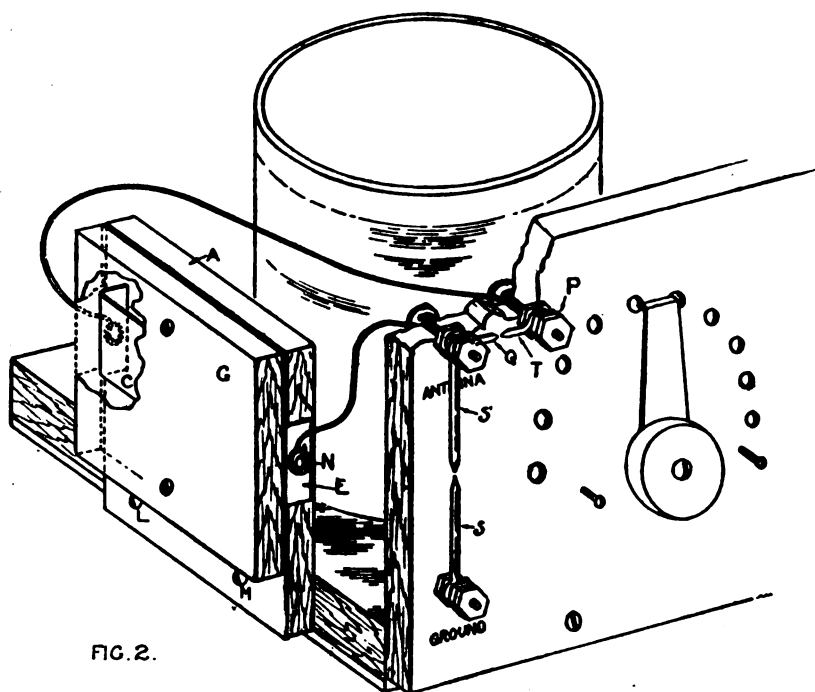


FIG. 2.

FIG. 2.—Method of mounting series-antenna condenser on single-circuit radio receiving set.

tenna" binding post is removed and a longer one substituted, so as to form parts *Q* and *S'*, Figure 2. A similar short piece of stiff copper wire *T* is attached between the first and second nuts of binding post *P*. There is a very short gap between wires *Q* and *T* and between *S'* and *S*. These gaps are for protective purposes when one forgets to throw the lightning switch to the grounded side. Another method of protection would be to install a lightning arrester in the antenna system. The arrester may be installed just outside or just inside of the building, preferably the former. This serves as an extra precaution when one forgets to throw the

lightning switch to the ground terminal when the receiving set is not being used.

If the condenser is mounted on the receiving set described in Circular No. 121, it may be placed as shown in Figure 3. In other words, it is mounted upon the vertical board which supports the primary coil tube previously described. The connections from the condenser to the binding post on the front panel of the two-circuit set are made as described above.

If the connections to the receiving set have been made as described in Circulars Nos. 120 or 121, the antenna lead-in wire is removed from the binding post marked "antenna" and connected to the new binding post which has been added to the front panel of the receiving set. (See *P*, Figs. 2 and 3.) The condenser is now included in the electrical circuit, together with the tuning coil, between the antenna and ground. This connection to the binding post *P* is used when it is desired to receive wave frequencies of approximately 1,000 kilocycles per second or above (wave lengths of

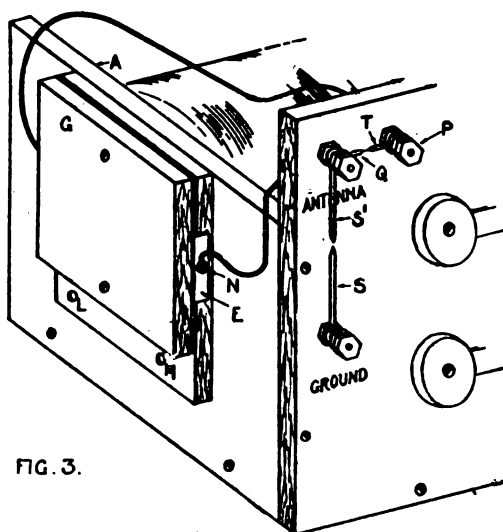


FIG. 3.

FIG. 3.—Method of mounting series-antenna condenser on two-circuit radio receiving set.

300 m or below). To receive wave frequencies of 1,000 kilocycles per second or below (wave lengths of 300 m or more) the antenna lead in is connected to the binding post marked "antenna" and the operation of the receiving set is then as described in Circulars Nos. 120 or 121. In either case the set is tuned to the desired wave frequency in the same manner as described in Circulars Nos. 120 and 121. The switches are set so as to include more turns of wire on the tuning coil (or the primary coil of the two-circuit receiving set) with the antenna lead in connected to *P* than when it is connected to the binding post marked "antenna" when tuning to a given wave frequency.

### III. DESCRIPTION OF TELEPHONE-SHUNT CONDENSER.

The parts used in the construction of the telephone-shunt condenser are (Fig. 4): A cap piece of heavy pasteboard or wood *A* about  $1\frac{3}{8}$  by 3 by  $\frac{1}{8}$  inches, a similar base of pasteboard or wood *B*  $1\frac{3}{8}$  by  $3\frac{7}{8}$  by  $\frac{1}{8}$  inches, 6 pieces of tin foil *C, D, E, F, G, H*,  $\frac{7}{8}$  by 7 inches, 7 pieces paraffined paper or mica *J, K, L, M, N, O, P*, each  $1\frac{1}{8}$  by 3 inches, 1 stiff paper clip or its equivalent (for temporary use), about 10 feet of No. 24 bare copper wire, and 2 round-

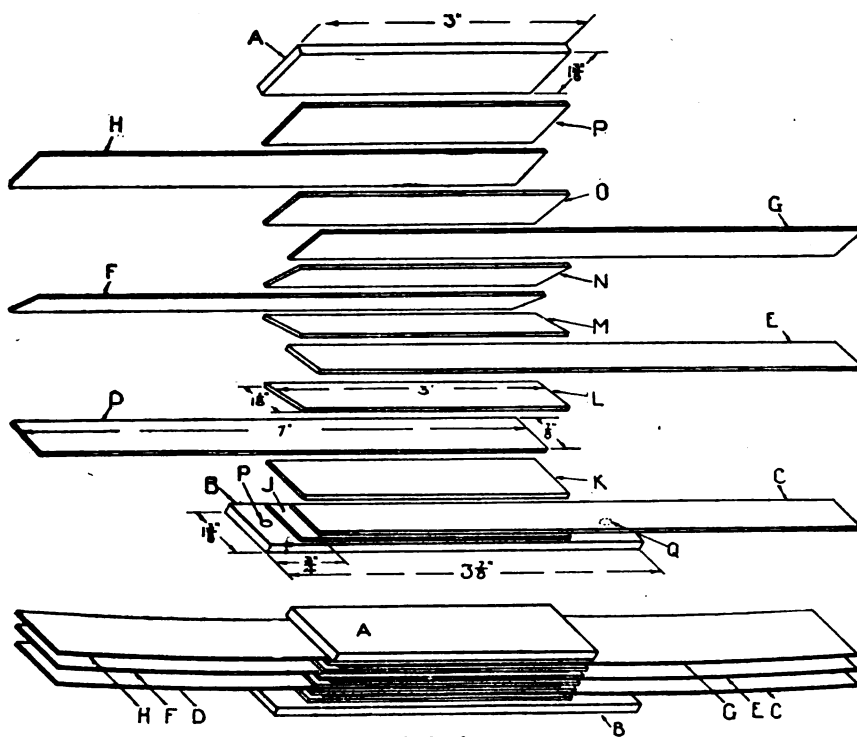


FIG. 4.—Assembly of telephone-shunt condenser.

head wood screws about  $\frac{1}{2}$  inch long. The several steps in the arrangement of these parts are shown in Figures 4, 5, and 6. The layers of paraffined paper and tin foil are alternated as shown, starting with a sheet of paraffined paper on the base *B*. The paper *J* is placed in the center of *B*, so that there will be a  $\frac{1}{8}$ -inch margin at the sides and  $\frac{1}{16}$ -inch margin at the ends of *B*. A sheet of tin foil *C* is then placed on the paper *J*, so that there will be a  $\frac{1}{8}$ -inch margin of paper uncovered on three sides. The tin foil *C* will then extend  $4\frac{1}{8}$  inches over the right-hand edge of the paper

$J$ , or  $3\frac{1}{8}$  inches over the right-hand edge of the base  $B$ . The paraffined paper  $K$  is placed on  $C$ , directly above  $J$ . The tin foil  $D$  is placed on  $K$ . The overhanging end of  $D$  extends to the left

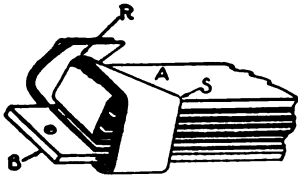


FIG. 5.—Method of forming terminals of telephone-shunt condenser.

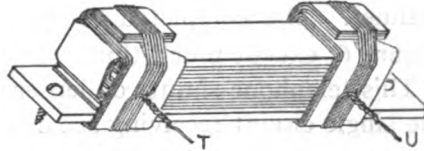


FIG. 6.—Completed telephone-shunt condenser.

instead of the right, as did  $C$ . The other three sides of  $D$  are  $\frac{1}{8}$  inch in from the three edges of  $K$ . This arrangement of alternate layers is followed until the seven paraffined papers and the six sheets of tin foil are placed in position. The cap piece  $A$  is then placed as shown in Figure 4.

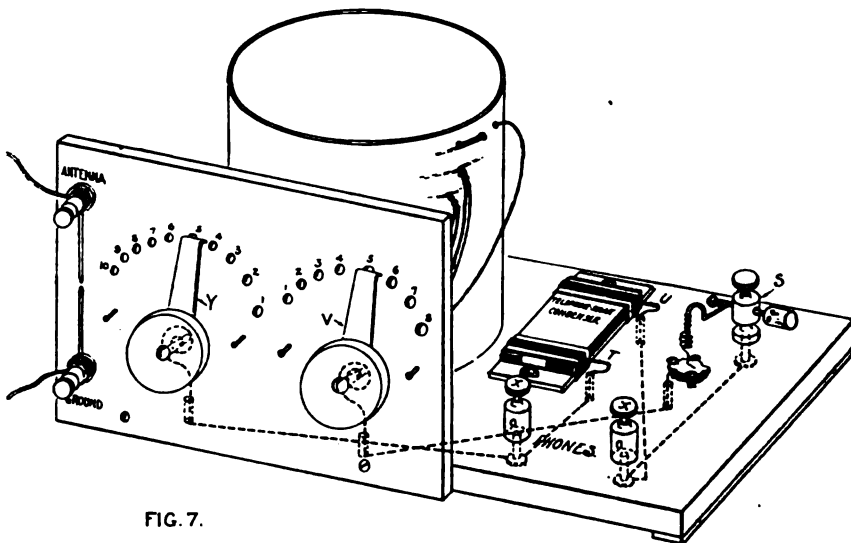


FIG. 7.—Method of mounting telephone-shunt condenser on single-circuit radio receiving set.

The condenser now appears as shown in Figure 4, except that the thickness of the condenser is much exaggerated here in order to better show the parts. A paper clip or other form of temporary clamp may be used to hold the parts firmly together. The tin-foil strips  $D$ ,  $F$ , and  $H$  are now bent back over the end of the cap piece

*A* and folded over at an angle of  $45^\circ$  (see line *RS*, Fig. 5), so that the tin foil may be wrapped evenly around the pieces *A* and *B* and secured by several turns of No. 24 bare copper wire (see Fig. 6). The tin-foil strips *C*, *E*, and *G*, Figure 4, are wrapped in the same manner. The completed condenser appears about as shown in Figure 6, except much thinner.

This telephone-shunt condenser just described may be added to the single-circuit receiving set described in Circular No. 120 or to the two-circuit receiving set described in Circular No. 121. The condenser is placed as shown in either Figures 7 or 8. A somewhat

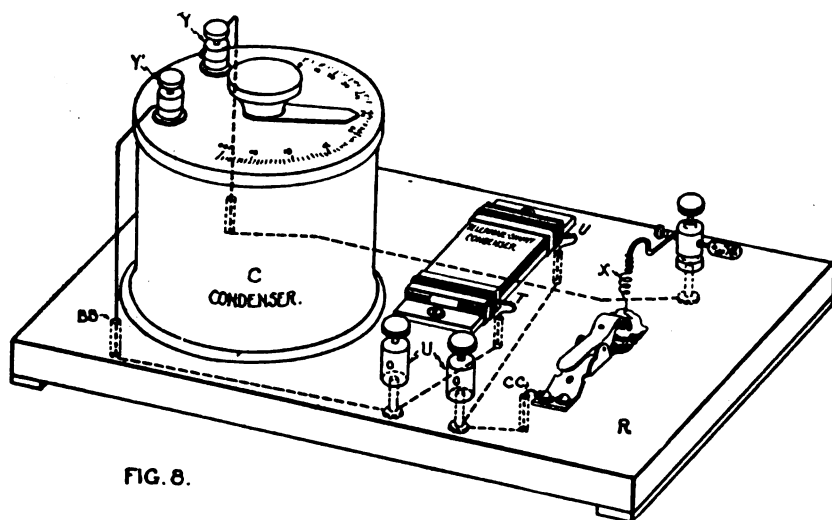


FIG. 8.

FIG. 8.—Method of mounting telephone-shunt condenser on variable-condenser-and-detector unit of two-circuit radio receiving set.

simpler plan is to screw the condenser to the underside of the receiving set baseboard. This saves drilling more holes in the baseboard in order to keep the wiring on the underside. No matter with which receiving set this condenser is used the two wires *T* and *U* (Figs. 7 and 8) are connected to the two telephone receiver binding posts marked "phones."

Fixed condensers may be purchased which will give about the same results as those described in this circular. The series-antenna condenser has a rated capacity of about 0.0003 microfarad (300 micromicrofarads). The telephone-shunt condenser has a capacity of approximately 0.0015 microfarad (1,500 micromicrofarads).

**IV. DESCRIPTION OF LOADING COIL.**

A loading coil is simply a coil of wire connected to the rest of the receiving equipment in such a manner that a variable number of its turns are included in the circuit between the antenna and the ground connection. When longer wave lengths (lower wave frequencies) are received, more turns are used on the coil.

The loading coil is shown at *A* in Figure 9A, and consists of 300 turns (about 5 ounces) of No. 28 double cotton-covered copper wire wound on a round cardboard box  $5\frac{3}{8}$  inches in diameter by about 8 inches long. An oatmeal box is used for the cardboard tube, with the cardboard cover glued to one end. Certain of the turns are provided with taps which are connected to switch contacts, so that the number of turns included in the circuit can be varied. One end of the wire is fastened at the closed end of the tube by weaving it through two holes  $\frac{1}{2}$  inch apart and  $\frac{3}{4}$  inch from the end. The free end of the wire projects about 10 inches. The wire is wound on the tube in a single layer, so that the turns lie closely and evenly together. When 10 turns have been wound a 10-inch tap is taken off. The method of winding and also one method of taking off the taps has been explained in Circular No. 120. Instead of using the simpler method of taking off taps as described in Circular No. 120, a somewhat more difficult and correspondingly more satisfactory method is used on this loading coil. After the given number of turns of wire have been wound on the tube a hole is punched through the tube just underneath the last turn, and, by using a small blunt tool or stick, a 10-inch loop of wire is pushed through this hole. A second hole is punched through the tube about  $\frac{1}{2}$  inch farther along the circumference and the loop pushed through this hole to the outside of the tube again. The loop may or may not be twisted as it emerges from the second hole. (See Fig. 9B.) When 10 more turns have been wound, another tap is taken off in the same manner. The arrangement of these taps is shown in the left half of Figure 9A. It will be noticed that there are 13 taps on the completed coil, counting the two ends of the wire at the start and finish. Each tap is slightly offset from the preceding one, so that the line of completed taps progresses about half way around the coil, as indicated in Figure 9A. After the wire is wound on the cardboard tube or oatmeal box it is placed in a warm oven to drive off the absorbed moisture. After the tube has dried for some time and while still warm, melted paraffin is brushed over the tube, inside and out. The paraffined tube is put

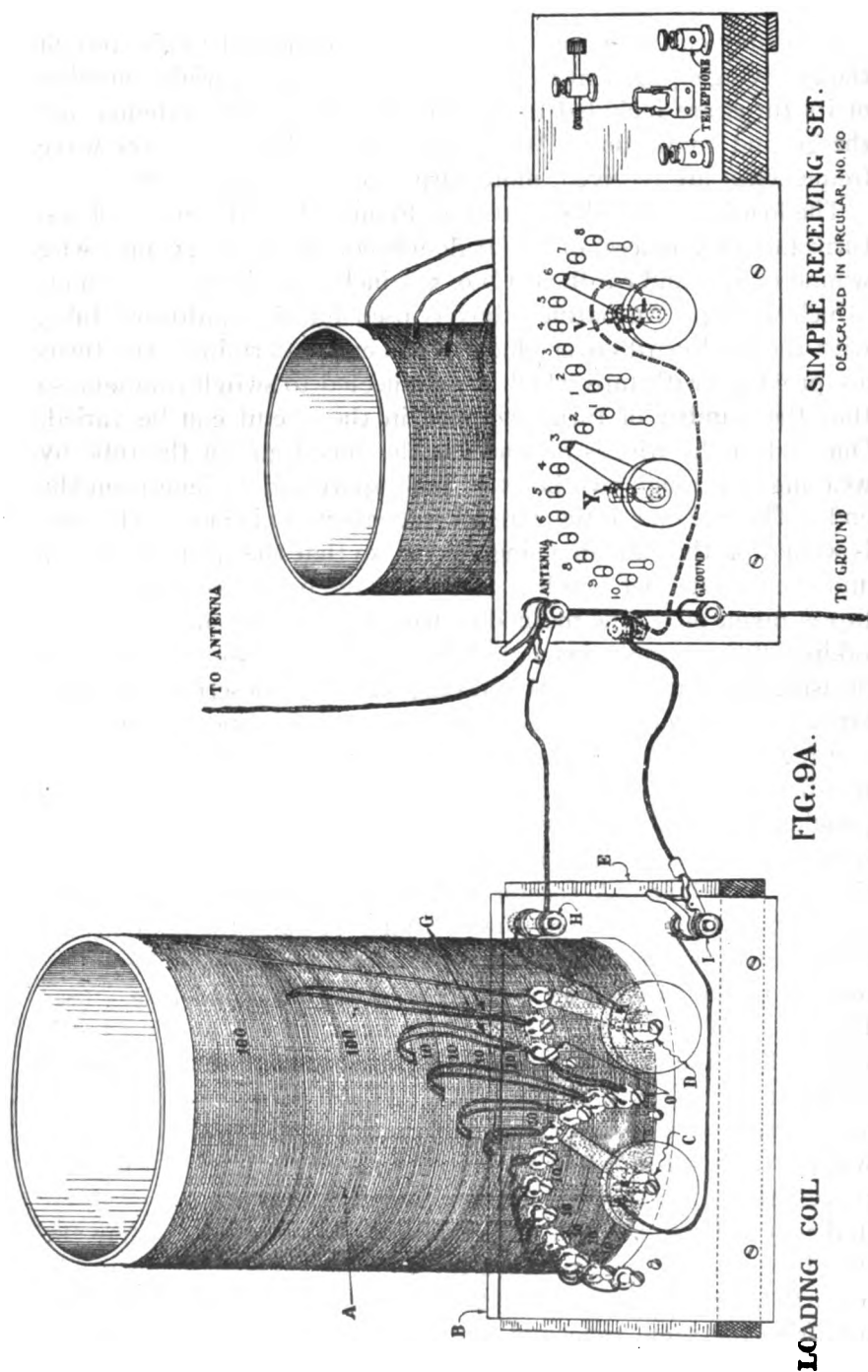


FIG. 9A.—Completed loading coil and connections to single-circuit radio receiving set.

back in the oven for a few minutes in order to more thoroughly impregnate the tube.

The switch panel *B* is made from a piece of dry wood about 7 inches long,  $4\frac{1}{2}$  inches wide, and  $\frac{1}{2}$  inch thick. Its general construction is similar to the switch panels described in Circulars Nos. 120 and 121. The two switch arms *C* and *D* which are used with this panel have also been described in Circular No. 120. Having drilled the holes for the two switch-arm bolts, the switch arms are placed in position and the knobs rotated in such a manner that the ends of the contact arms describe arcs upon which the contact points are to be placed. The holes for the switch contact bolts are then drilled, the spacing between contacts depending upon the width of the end of the switch arms as well as upon the kind of contacts which are used. For the switch arm *C* there are 11 contacts and for the switch arm *D* there are 3 contacts, as shown. The wood base *E* is a block of wood about 7 inches square and  $\frac{3}{4}$  inch thick.

(a) ASSEMBLY AND WIRING.—Before any of the parts are assembled the base and panel are treated with paraffin, as described in Circular No. 120, or they may be thoroughly dried and coated with a good grade of varnish which will not absorb moisture, such as a spar varnish. Shellac is not used. The panel *B* is fastened to the base *E*, and the coil *A* is placed in position so that the row of taps faces the rear of the panel. The coil is fastened in this position by small wood screws passing through the

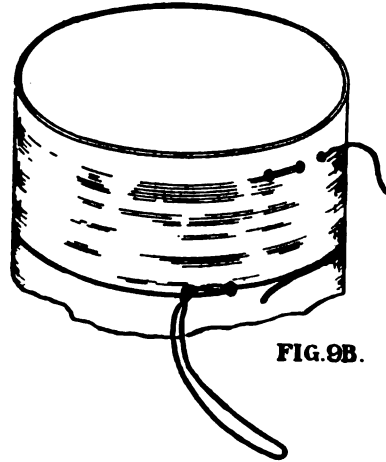


FIG. 9B.—Method of taking off tape when winding loading coil.

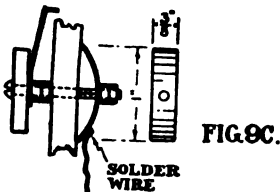


FIG. 9C.—Detail of switch arm used on loading coil.

cardboard end, each screw being provided with a washer. The two switch arms with the necessary contact bolts are placed in position on the panel. A wire connection is made between switch arm *D* and binding post *H* and between switch arm *C* and binding post *I*, as explained in Circular No. 120, or a spring washer is

slipped over each switch-arm bolt at the rear of the panel and the wires soldered to these. (See Fig. 9C.) The several taps from the coil are cut off to a length sufficient to reach from the coil to the contacts. The insulation is scraped from the ends of the wires and the ends of the double taps twisted together below the point *G*. (See *G*, Fig. 9A.) The taps are fastened between the nuts and washers of the proper contact bolts as shown in the left half of Figure 9A. It will be noticed that the two contact points marked *O* are connected together. This is done so that when the switch arms are placed on these contacts there will be no turns of wire on the loading coil included in the circuit.

This loading coil is used in connection with the receiving set described in Circular No. 120, except as noted below under "Use with two-circuit set." The method of making the connections is shown in Figure 9A. A 10-inch copper wire with a battery clip at one end is fastened to the binding post *H*, with the clip attached to the receiving set binding post marked "antenna." The wire originally leading from the back of the "antenna" binding post was connected to the back of the switch-arm bolt *V*. This wire is removed from the back of the "antenna" binding post and attached to a new bolt or binding post fastened to the baseboard of the simple receiving set. This bolt or binding post is located just at the rear of the receiving set binding post marked "ground." A 10-inch piece of copper wire is attached to this new bolt or binding post, with a battery clip attached at the end toward the loading coil binding post *I*. The wire leading from the crystal to the rear of the "antenna" binding post, as described in Circular No. 120, remains as it was. If one end of this wire was originally connected to the wire leading to the switch-arm bolt *V*, or directly to *V*, this end is removed and connected to the rear of the "antenna" binding post. All other wiring is the same as described in Circular No. 120.

(b) METHOD OF OPERATING.—The wire leading to the antenna is connected to the binding post marked "antenna," and the wire leading to the ground is connected to the binding post marked "ground," as before. In order to receive messages transmitted at wave frequencies between 500 and 1,500 kilocycles per second (wave lengths between 600 and 200 m), the switch arms *C* and *D* on the loading-coil panel are both set on the contacts marked *O*. When receiving at the shorter waves (200 to 600 m), it is better to remove the battery clip from the "antenna" binding post and

put the clip previously attached to *I* in its place; that is, attach the wire from the new binding post to the "antenna" binding post. The loading coil is thus entirely disconnected from the receiving set and should be removed some distance from it. The operation of the receiving set is then exactly the same as described in Circular No. 120. In order to receive messages transmitted at wave frequencies less than 500 kilocycles per second (wave lengths over 600 m), the loading coil is again connected as shown in Figure 1A and the switches on the loading-coil panel are adjusted so that the proper number of turns is included in the circuit. The switches on the panel of the original receiving set are set so that they include all of the wire on the coil; that is, set switch arm *Y* on contact point 10 and switch arm *V* on contact point 8, Figure 1A. (See also Fig. 3, p. 10, Circular No. 120.) The switch *D* on the loading-coil panel is set to the extreme left on contact *O*, and the switch arm *C* is rotated slowly over its entire range. If signals are not heard, the switch arm *D* is set on the next contact to the right and the switch arm *C* is again rotated over all of its contacts. If the signals are still not heard, the switch arm *D* is placed on the contact to the extreme right and the switch *C* again rotated over its contacts. When the transmitting station is heard, the signals may be improved by adjusting the right-hand switch arm *V* of the original receiving set, at the same time changing slightly the setting of the switch arm *C*.

(c) **USE WITH TWO-CIRCUIT SET.**—The loading coil as described herein has been found quite satisfactory in extending the wave length range of the single-circuit receiving set described in Bureau of Standards Circulars No. 120. The experimenter may be interested in trying various ways in which to extend the wave length range of the two-circuit set as is described in Bureau of Standards Circular No. 121. For the general guidance of the experimenter the following methods will give results with varying degrees of satisfaction: Use of the loading coil in one of the two circuits and no loading in the other (this means that one of the circuits will not be tuned to the wave, and hence the results will be relatively poor); use of loading coil in the primary, together with a fixed condenser (like those described earlier in this circular) in parallel with the variable condenser; use of loading coil in one of the two circuits and winding more wire on the coil in the other circuit.

The suggestions given above assist the experimenter in obtaining a better idea of the tuning of a two-circuit receiving set. For satisfactory results, however, the connections are made so

that the secondary circuit is not used for receiving wave frequencies below the range of the two-circuit set. This is accomplished by connecting a double-pole, double-throw switch to the rest of the apparatus in such a manner that when the switch is thrown in one position the connections are the same as a single-circuit receiving set. Throwing the switch in the other position then connects the apparatus for use as a two-circuit receiving set. The method of connecting this switch is as follows: The switch is first located in a convenient position near the two-circuit tuner. The wires connecting the secondary terminals of the tuner to the terminals of the variable condenser are next removed. The pivot terminals of the switch are now connected to the two terminals of the variable condenser, the switch is thrown so that it makes contact with one pair of terminals, and these two terminals are then connected to the terminals of the secondary coil. The other two terminals of the switch are connected to the "antenna" and "ground" binding posts of the receiving set, respectively.

Throwing the switch to one side disconnects the secondary coil from the circuit. The secondary coil is then moved about a foot from the primary coil, the variable condenser set at zero, and the loading coil then tuned as previously described. When the switch is thrown to the other position, the two-circuit set is operative.

## V. APPROXIMATE COST OF PARTS.

The parts listed below are only those used in the condensers and loading coil. The receiving-set parts are listed in Circulars Nos. 120 and 121. All of these parts together constitute a complete receiving outfit which has a rather wide range of wave frequencies, as explained in the first part of this circular. The approximate cost of the complete equipment is therefore the sum of the amounts given below and the amount given in Circular No. 120 or that in Circular No. 121.

### Series-antenna condenser:

2 metal strips (copper, brass, or aluminum) .....	\$0. 10
3 sheets of mica (if used) .....	. 20
1 binding post (any type) .....	. 10
6 wood screws .....	. 10
2 small wooden blocks .....	
Paraffin .....	
Paper .....	
<b>Total</b> .....	<b>. 50</b>

**Telephone-shunt condenser:**

About 40 square inches of heavy tin foil.....	\$. 25
2 screws for mounting condenser.....	. 05
2 small pieces of heavy cardboard or thin wood.....	
Paraffin.....	
Paper.....	
<b>Total.....</b>	<b>. 30</b>

**Loading coil:**

5 ounces No. 28 copper wire, double cotton covered.....	. 80
2 battery clips.....	. 20
2 switch knobs and blades, complete.....	1. 00
14 switch contacts, nuts, and washers.....	. 60
1 cardboard box (5½ inches diameter by 8 inches long).....	
3 binding posts.....	. 45
Wood for panel and base.....	
Paraffin.....	
<b>Total.....</b>	<b>3. 05</b>

WASHINGTON, November 21, 1922.



DEPARTMENT OF COMMERCE

# CIRCULAR

OF THE

# BUREAU OF STANDARDS

No. 138

**A DECIMAL CLASSIFICATION OF RADIO SUBJECTS—  
AN EXTENSION OF THE DEWEY SYSTEM**

MARCH 21, 1923



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1923



# A DECIMAL CLASSIFICATION OF RADIO SUBJECTS— AN EXTENSION OF THE DEWEY SYSTEM.

## ABSTRACT.

Many workers in the growing field of radio communication have felt the necessity for a systematic scheme of classification which could be used for classifying and filing references to current radio literature as well as other radio material, such as drawings, books, and reports. Several years ago the radio laboratory of the Bureau of Standards felt the need for a such a classification in connection with its own work. After some trials it appeared that a decimal system of classification would be very useful for this purpose, thus giving a classification by subject in which the numbers used show not only the relative positions of the material in the files but also the subject matter. The whole subject of radio communication is put in its proper place in the Dewey decimal classification—621.384, but it is suggested that in a purely radio library these figures be abbreviated by the use of the letter "R" as a prefix for the numbers which designate the divisions of the subject—radio communication. The main headings into which the subject of radio are divided are as follows:

- R000 Radio communication.
- R100 Radio principles.
- R200 Radio measurements and standardization.
- R300 Radio apparatus and equipment.
- R400 Radio communication systems.
- R500 Applications of radio.
- R600 Radio stations: Equipment, operation, and management.
- R700 Radio manufacturing.
- (R800) Nonradio subjects.
- R900 Miscellaneous radio.

An abbreviated classification is provided for the use of small libraries or collections, and an alphabetical index enables one to refer readily to the classification number of any subject desired.

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## I. INTRODUCTION.

### 1. NEED FOR CLASSIFICATION.

The radio laboratory of the Bureau of Standards has, in common with other workers in the radio field, felt the need for a systematic scheme of classification for subjects in radio science and engineer-

ing. This need has been felt not only for use in classifying the references to current radio publications but also for classifying other radio material, such as drawings, books, reports, etc. In an effort to fill the need for a radio classification the present extension of the Dewey decimal system has been prepared.

Such a system makes it easy to place books on related subjects near together on the shelves or to file references on the same subject all in the same group and not by the order of their addition to the collection or file. If a classification is to be of the most use any part of it must be capable of expansion, or it must be possible to disregard any part of the classification without interfering with the usefulness of the remaining parts.

## **2. EXTENSION OF THE DEWEY DECIMAL SYSTEM OF CLASSIFICATION.**

Under the Dewey decimal system, of which the present classification is an extension, classification is by subject, numbers being used to show the relative positions of the books, cards, or other material. The numbers, therefore, show both what the material is (that is, its subject matter) and where the material is (that is, its location on the shelves or in the files). In the classification list the indentation and the figures prefixed to each item show the rank of each subject in the classification.

Accompanying the classification is an index which is arranged in the usual alphabetical order. References are made in this index to the subject classification number rather than to pages or to arbitrary shelf numbers. The index is used in determining the number to assign to a given item or material or to learn where to place it in the files. The index is also used by any person desiring to locate the material covering a given subject. The reference number tells him immediately where he will find all material on that and on related subjects.

## **3. OUTLINE OF CLASSIFICATION.**

The whole subject of radio is put in its proper place in the Dewey classification—621.384. The relation of this place to the general field is shown by the following table:

Class	600.	Useful arts.
Division	20.	Engineering.
Section	1.	Mechanical.
	.300	Electrical.
	.080	Communication.
	.004	Radio.

In a strictly radio library or office it is convenient to represent the figure 621.384 by "R," and this abbreviation is used below in the further classification of radio. Thus—

- R211 Resonance methods of measuring wave length.
- R513 Applications of radio to fog signaling.

## II. SUMMARY OF RADIO CLASSIFICATION.

Radio communication is divided into a general class and a number of other classes, as follows:

- R000 Radio communication.
- R100 Radio principles.
- R200 Radio measurements and standardization.
- R300 Radio apparatus and equipment.
- R400 Radio communication systems.
- R500 Applications of radio.
- R600 Radio stations: Equipment, operation, and management.
- R700 Radio manufacturing.
- (R800) Nonradio subjects.
- R900 Miscellaneous radio.

### 1. MODIFICATIONS AND VARIATIONS.

While some of the details of the Dewey system seem at the present time to be illogical (for example, electrical engineering a subdivision of mechanical engineering), the system has been widely adopted, and more confusion would result from attempting to change it into a more logical form than results from the arbitrary use of the established practice. In the present classification the Dewey system has been adopted and some of its general features are found specially advantageous. For example, all general material under a given class should be put under the class itself (frequently having a final figure 0). The ninth division under any class is frequently reserved for items which are as yet of too small importance to classify separately. This should not, however, be confused with the first item under each class which is used for general material applied to many or all of the subdivisions under it.

The class (R800) is left vacant for future use. However, in a strictly radio library or office having little material other than radio to classify, it will be found convenient to use this space for nonradio subject matter. Such material should be given its regular class number according to the Dewey system. If it were arranged in strictly numerical order, some of this material would come before radio and some after radio. But by choosing arbitrarily to use the space denoted by (R800) for this purpose it is

possible to arrange the nonradio material in classified order, but to keep it subordinate to a larger volume of radio material. Thus a number of nonradio items are listed under (R800) in the complete table of class numbers below.

For users having only a small amount of material to classify, an abbreviated classification is suggested. This abbreviated classification is given separately before the main table. Obviously, other items may be added or some of these omitted, depending on the individual needs.

Specific books or papers under a given class or subdivision may be denoted by a small letter, the assignment being according to subject, author, order of accession, or any other consideration depending on the circumstances

In a card file of references to periodical literature it is convenient to arrange the cards under each final class or subdivision in alphabetical order by the names of subjects or authors.

## 2. CLASSIFICATION AS TO FORM.

This classification is mainly by *subject* or *content*, regardless of form. For material covering a general field an additional form distinction is found practically useful. For classification as to form the following set of numbers may be used in connection with the number corresponding to the subject covered, in every case in which the number so formed has not already been employed for another signification.

The sequence of figures constituting the form number is simply placed to the right of the sequence of figures constituting the class number. If the class number already ends in one or two zeros, as 500 or 510, these zeros are disregarded in making up the combined number. Thus a periodical on any subject has the subject number followed by 05.

### Examples:

- R504 Periodicals covering applications of radio.
- R510. 4 Periodicals covering applications of radio to navigation.
- R512. 04 Periodicals covering radio beacons.
- R512. 007 Laws regarding radio beacons.

An example of the form classification is given in the complete table of class numbers under R620, Radio stations, operation and management.

- 001 Statistics.
- 002 Quantities; cost.
- 003 Contracts; specifications.

- 004 Designs; drawings.
- 005 Executive; administrative; rules.
- 006 Working; maintenance.
- 007 Laws; regulations.
- 008 Patents.
- 009 Reports of tests; bulletins.
  - 01 Theory; methods; programs.
  - 02 Textbooks; outlines; manuals.
  - 03 Cyclopedias; dictionaries.
  - 04 Essays; addresses; lectures; letters; papers.
  - 05 Periodicals; magazines; reviews; bibliography; publications.
  - 06 Societies; associations; transactions; exhibitions.
  - 07 Education; training; museums.
  - 08 Tables; calculations; charts; maps.
  - 09 History; progress; development; biographical.
- Thus R470. 9 History of development of wire radio systems.
  - or R600. 3 Contracts for radio stations.

### III. ABBREVIATED CLASSIFICATION OF RADIO SUBJECTS.

For small collections or files in which detailed classification is not required, the following abbreviated list of classes may be useful:

- R000 **RADIO COMMUNICATION.**
- R050 ..... Publications.
- R060 ..... Societies.
- R090 ..... History.
- R100 .... **Radio principles.**
- R110 ..... Radio waves.
- R120 ..... Antennas.
- R130 ..... Electron tubes.
- R140 ..... Radio circuits.
- R150 ..... Generating apparatus.
- R160 ..... Receiving apparatus.
- R190 ..... Other radio principles.
- R200 .... **Radio measurements and standardization.**
- R210 ..... Frequency; wave length.
- R220 ..... Capacity; dielectric constant.
- R230 ..... Inductance.
- R240 ..... Resistance; decrement; phase difference; power loss.
- R250 ..... Current.
- R260 ..... Voltage.
- R270 ..... Signal intensity.
- R280 ..... Properties of materials.
- R290 ..... Other measurements.
- R300 .... **Radio apparatus and equipment.**
- R320 ..... Antennas.

R330	.....	Electron tubes.
R340	.....	Electron tube apparatus.
R350	.....	Generating apparatus; transmitting sets.
R360	.....	Receiving apparatus; receiving sets.
R380	.....	Parts of circuits; instruments.
R400	.....	<b>Radio communication systems.</b>
R410	.....	Modulated wave systems.
R411	.....	Spark.
R412	.....	Radio telephone systems.
R413	.....	Low-frequency modulating systems.
R414	.....	High-frequency modulating systems.
R420	.....	Continuous wave systems.
R421	.....	High-frequency alternator.
R422	.....	Arc.
R423	.....	Electron tube.
R430	.....	Interference elimination.
R440	.....	Remote control (by wire).
R450	.....	Linkage.
R460	.....	Duplex and multiplex systems.
R470	.....	Wired radio.
R480	.....	Relay systems.
R490	.....	Other systems.
R500	.....	<b>Applications of radio.</b>
R510	.....	Navigation.
R520	.....	Aviation.
R530	.....	Commercial and special services.
R540	.....	Private.
R550	.....	Broadcasting.
R560	.....	Military; naval.
R570	.....	Distant control by radio.
R580	.....	Other applications.
R590	.....	National developments.
R600	.....	<b>Radio stations: Equipment, operation, and management.</b>
R610	.....	Equipment; station descriptions.
R620	.....	Operation and management.
R700	.....	<b>Radio manufacturing.</b>
R710	.....	Factories.
R720	.....	Processes.
R740	.....	Sales.
R800	.....	<b>Nonradio subjects.</b>
R900	.....	<b>Miscellaneous radio</b>

#### IV. COMPLETE TABLE OF CLASS NUMBERS.

[The numbers marked with an asterisk (\*) are not found in the Dewey decimal classification, but are inserted here for convenience.]

##### **R000 RADIO COMMUNICATION.**

- R001 .....Statistics.
- R003 .....Contracts.
- R004 .....Design.
- R005 .....Executive; administrative; personnel.
- R006 .....
- R007 .....Laws; Regulations.
- R007. 1 .....United States laws and regulations.
- R007. 2 .....United States radio inspection service.
- R007. 3 .....
- R007. 4 .....Canada.
- R007. 5 .....British Empire (except Canada).
- R007. 6 .....France.
- R007. 7 .....Germany.
- R007. 8 .....Other countries.
- R007. 9 .....International conferences.
- R008 .....Patent specifications.

(These should ordinarily be distributed according to the subject of the patent.)

- R009 .....Reports; bulletins.
- R010 ....Research.
- R020 ....Textbooks.
- R030 ....Terminology; symbols.
- R040 ....Lectures.
- R050 ....Publications.
- R051 .....Books.
- R053 .....Periodicals.
- R055 .....Bibliography.
- R060 ....Societies; meetings.
- R070 ....Education; training.
- R071 ....Courses of study.
- R073 ....Training of operators.
- R080 ....Collections, tables, miscellanies.
- R081 .....Tables.
- R082 .....Nomograms.
- R083 ....Humor.
- R084 ....Maps and charts.
- R090 ....History.
- R090. 1 .....United States.
- R090. 2 .....British Empire.
- R090. 3 .....France.
- R090. 4 .....Germany; Austria.

- R090. 5 ..... Italy; Spain; Portugal.
- R090. 6 ..... Norway; Sweden; Denmark.
- R090. 7 ..... Asia; Africa.
- R090. 8 ..... South America.
- R090. 9 ..... Other countries.
- R091 ..... Radio telegraphy.
- R094 ..... Radio telephony.
- R097 ..... Biographical.
- R100 ..... **Radio principles.**
- R110 ..... Radio waves.
- R111 ..... Electromagnetic theory.
- R112. 1 ..... Radiation.
- R112. 6 ..... Absorption (reception).
- R113 ..... Transmission phenomena.
- R113. 1 ..... Fading.
- R113. 2 ..... Daily variations; seasonal variations.
- R113. 3 ..... Directional variations.
- R113. 4 ..... Ionization; Heaviside layer.
- R113. 5 ..... Meteorological.
- R113. 55 ..... Tropical radio.
- R113. 6 ..... Reflection; refraction; diffraction.
- R113. 7 ..... Transmission formulas; range.
- R113. 8 ..... Eclipses.
- R113. 9 ..... Wave front angle.
- R114 ..... Strays.
- R115 ..... Directional properties.
- R116 ..... Waves on wires.
- R120 ..... **Antennas.**
- R121 ..... Condenser type antennas (ordinary elevated type)  
with ground.
- R122 ..... Condenser type antennas (ordinary elevated type)  
with counterpoise.
- R123 ..... Ground and underground antennas.
- R124 ..... Coil antennas.
- R125. 1 ..... Direction finding.
- R125. 6 ..... Directive antennas (transmitting in a particular di-  
rection).
- R126 ..... Ground connections.
- R127 ..... Antenna constants.
- R128 .....
- R129 ..... Special types.
- R130 ..... Electron tubes.
- R130. 3 ..... Nomenclature.
- R130. 4 ..... Principles of design.
- R131 ..... Characteristic curves; general properties.

R132	.....	Amplifying action.
R132. 1	.....	Inductive coupling.
R132. 2	.....	Capacitive coupling.
R132. 3	.....	Resistance coupling.
R133	.....	Generating action.
R134	.....	Detector action.
R134. 4	.....	Regenerative action.
R134. 45	.....	Superregenerative action.
R134. 5	.....	
R134. 6	.....	
R134. 7	.....	Heterodyne, autodyne.
R134. 75	.....	Superheterodyne.
R134. 8	.....	Reflex action.
R135	.....	Modulating action.
R136	.....	Input impedance.
R137	.....	Output impedance.
R138	.....	Electron emission; ionization.
R139	.....	Other electron tube principles.
R140	....	Radio circuits.
R141	.....	Simple radio circuits.
R141. 1	.....	Frequency.
R141. 2	.....	Resonance.
R141. 3	.....	Impulse excitation.
R142	....	Coupled circuits.
R142. 1	.....	Direct coupling.
R142. 3	.....	Inductive coupling.
R142. 5	.....	Capacitive coupling.
R143	....	Damping; decrement.
R144	....	High-frequency resistance.
R145	....	Reactance.
R145. 3	.....	Inductance.
R145. 5	.....	Capacity.
R146	....	Harmonics.
R147	....	Beats.
R148	....	Modulation.
R148. 1	.....	Distortion.
R149	....	Rectification.
R150	..	Generating apparatus.
R151	.....	
R152	.....	Spark gaps.
R153	.....	Arcs.
R154	.....	Alternators.
R155	.....	
R156	.....	Transformers.
R160	.....	Receiving apparatus.
R161	.....	Sensitivity.

R162	.....	Selectivity.
R170	.....	
R180	.....	
R190	.....	Other radio principles.
R200	.....	<b>Radio measurements and standardization.</b>
R201	.....	General methods and apparatus.
R201. 2	.....	Uses of electron tubes in radio measurements.
R201. 5	.....	Shielding and grounding.
R201. 6	.....	High-frequency bridge.
R201. 7	.....	Use of high-frequency oscillograph.
R202	.....	Resonance methods.
R203	.....	Harmonic methods.
R204	.....	Null methods.
R205	.....	Substitution methods.
R210	.....	Frequency; wave length.
R211	.....	Resonance methods.
R212	.....	
R213	.....	Harmonic methods.
R220	.....	Capacity.
R220. 1	.....	Capacity meters.
R223	.....	Dielectric constant.
R225	.....	Capacity of coils.
R230	.....	Inductance.
R231	.....	Self inductance.
R235	.....	Mutual inductance.
R240	.....	Resistance; decrement; phase difference; power loss.
R241	.....	Resistance-variation method.
R242	.....	Reactance-variation method.
R243	.....	Substitution method.
R244	.....	Calorimeter methods. ( <i>See also</i> 536.6.)
R250	.....	Current.
R251	.....	Ammeters.
R251. 1	.....	Hot-wire.
R251. 2	.....	Thermoelement.
R251. 3	.....	Current transformer.
R251. 4	.....	Electrodynamometer.
R251. 5	.....	Einthoven galvanometer.
R251. 6	.....	Bolometer bridge.
R260	.....	Voltage.
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R262	.....	Sparking distance.
R263	.....	Electrostatic voltmeters.
R264	.....	
R265	.....	
R266	.....	

R267	-----
R268	-----
R269	----- Other voltmeters for radio frequencies.
R270	----- Signal intensity.
R271	----- Shunted telephone method.
R272	----- Audio-frequency comparison method.
R273	----- Radio-frequency comparison method.
R274	-----
R275	----- Modulation.
R280	----- Properties of materials.
R281	----- Electrical insulating materials.
R281. 1	----- Laminated.
R281. 11	----- Phenolic binders.
R281. 12	----- Shellac binders.
R281. 13	----- Fiber.
R281. 2	----- Molded.
R281. 21	----- Phenolic binders.
R281. 22	----- Shellac binders.
R281. 23	----- Pitch binders.
R281. 31	----- Porcelain.
R281. 33	----- Glass.
R281. 35	----- Rubber.
R281. 37	----- Gutta-percha.
R281. 38	----- Mica.
R281. 383	----- Built-up mica.
R281. 41	----- Textiles.
R281. 42	----- Paper.
R281. 426	----- Pulpboard.
R281. 43	----- Wood.
R281. 44	----- Wax.
R281. 45	----- Pitch.
R281. 46	----- Paraffin.
R281. 47	----- Varnish.
R281. 48	----- Shellac.
R281. 49	----- Oil.
R281. 60	----- Resins.
R281. 61	----- Natural resins.
R281. 65	----- Synthetic resins.
R281. 70	-----
R281. 71	----- Quartz.
R281. 72	----- Marble.
R281. 73	----- Granite.
R281. 74	----- Slate.
R281. 75	----- Lava.
R281. 76	----- Asbestos.

R281. 77	Sulphur.
R281. 78	Amber.
R281. 79	Celluloid.
R281. 80	Cellulose esters.
R281. 81	Oxide coatings.
R281. 82	Vitrified clay products.
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R281. 9	Miscellaneous insulating materials.
R282	Electrolytes.
R283	Magnetic materials.
R284	Conductors.
R284. 1	Metals.
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R284. 13	Tungsten.
R284. 3	Pyroelectric.
R290	Other measurements.
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R320	Antennas.
R320. 6	Antenna switches.
R320. 8	Towers.
R321	Condenser type antennas (ordinary elevated type) with ground.
R322	Condenser type antennas (ordinary elevated type) with counterpoise.
R323	Ground and underground antennas.
R324	Coil antennas.
R325. 1	Direction finders.
R325. 6	Directive antennas (transmitting in a particular direction).
R326	Ground connections.
R327	Artificial antennas.
R328	Multiple-tuned antennas.

- R329 .....Special types of antennas. (For airplane antennas  
see R525.)
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- R330. 9 .....History.
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- R342. 15 .....Amplifier transformer.
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- R342. 3 .....Capacitive coupling.
- R342. 4 .....
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- R342. 6 .....Radio-frequency amplifiers.
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- R343 .....Electron tube receiving sets.
- R343. 5 .....Heterodyne sets.
- R343. 7 .....Alternating-current supply.
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- R344. 3 .....Transmitting sets.
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512	.....	Algebra.
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513	.....	Geometry.
514	.....	Trigonometry.
515	.....	Descriptive geometry.
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520	.....	Astronomy.
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531	.....	Mechanics.
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533	.....	Pneumatics.
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534	.....	Sound.
534. 3	.....	Tuning forks.
534. 83	.....	Signals in navigation.
535	.....	Light. (For Light signaling see 623.731.)
535. 3	.....	Photo-electric phenomena.
536	.....	Heat.
536. 33	.....	Radiation; general theory.
537	.....	Electricity.
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537. 23	.....	Electrostatic generators.
537. 26*	.....	Corona discharge.
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537. 61*	.....	Negative resistance.
537. 63*	.....	Corbino effect.
537. 65*	.....	Piezoelectric phenomena.
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537. 67*	.....	Experimental plotting of electrical fields.
537. 7	.....	Wave form analysis.
537. 87	.....	Physiological electrical phenomena.
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539	.....	Molecular physics.
540	.....	Chemistry.
541. 3	.....	Physical chemistry.
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550	.....	Geology.
551. 5	.....	Weather; meteorology.

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621. 3	.....	Electrical engineering.
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621. 313. 23	.....	Direct-current generators.
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621. 313. 3	.....	Alternating-current machinery.
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621. 314. 3	.....	Transformers.
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621. 317. 3	.....	Switches.
621. 317. 4	.....	Rheostats.
621. 319. 2	.....	Transmission lines.
621. 325	.....	Incandescent arcs.
621. 326	.....	Incandescent filament lamps.
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621. 327. 7	.....	X-ray tubes.
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621. 374. 3	.....	Voltmeters.
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621. 374. 41*	.....	Ammeters.
621. 374. 45*	.....	Galvanometers.
621. 374. 6	.....	Wattmeters.
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621. 385. 91*	.....	Telegraphone.
621. 385. 93*	.....	Thermophone.
621. 385. 95*	.....	Condenser transmitters.
621. 39	.....	Other applications of electricity.

623. 731	.....	Light signals.
623. 8	.....	Steamships.
629. 13	.....	Aeronautics.
629. 145	.....	Aerial navigation.
629. 18	.....	Airplane construction.
658	.....	Business methods.
R900	.....	Miscellaneous.

## V. ACKNOWLEDGMENTS.

The general scheme used in the above classification follows the decimal classification and relative index of Melvil Dewey, published by the Forest Press, Lake Placid, N. Y. An extension of the Dewey decimal system of classification applied to engineering industries by L. P. Breckenridge and G. A. Goodenough has been issued by the University of Illinois Engineering Experiment Station as Bulletin No. 9 (1912). Both the Dewey classification and the University of Illinois extension give a short classification of radio communication, but the recent advances in this subject have caused it to outgrow these limitations. Valuable criticism of a preliminary radio subject classification have been received from Arthur Bessey Smith and Harrison W. Craver, and it is partly owing to their recommendation and to the widespread use of the Dewey system that the decimal classification has been adopted. Attention is also called to a "Proposed classification for an engineering library" published in the Transactions of the American Society of Civil Engineers, volume 82, page 1618, December, 1918. The classification there proposed is decimal in form but departs quite radically from the Dewey system. The classification of radio there is very meager.

## VI. INDEX TO RADIO CLASSIFICATION.

To use this index, find the subject desired in its alphabetical place in the following list. The number after it is its class number, and refers to the place where the topic will be found, in numerical order of class numbers, on the shelves or in the subject catalogs.

All class numbers are decimals; that is, R251.1, Hot-wire ammeters, comes before R260, Voltage measurements. Labels on the shelves, drawer fronts, or cards guide readily to the class number sought.

Under this class number will be found the resources of the library on the subject desired. Other subjects near the one sought may often be consulted with profit; for example, Electron tubes

is the topic wanted and the index refers to R330, but R340, Electron-tube apparatus, also contains much on the subject of electron tubes, as well.

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Washington, November 28, 1922.





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**DEPARTMENT OF COMMERCE.**

U. S. BUREAU OF STANDARDS.  
" GEORGE K. BURGESS, Director.

**CIRCULAR OF THE BUREAU OF STANDARDS.**

**No. 139.**

(Issued June 15, 1923.)

**UNITED STATES GOVERNMENT SPECIFICATION FOR  
DRY CELLS.**

**FEDERAL SPECIFICATIONS BOARD.**

**STANDARD SPECIFICATION NO. 58.**

This specification was officially adopted by the Federal Specifications Board on June 15, 1923, for the use of the Departments and Independent Establishments of the Government in the purchase of dry cells.

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**1. DEFINITIONS.**

(a) Dry cells to be included under these specifications shall fulfill the following requirements in addition to the other paragraphs of these specifications:

- (1) To be sal ammoniac cells with depolarizer.
- (2) To have a nonspillable electrolyte and to be free from leakage during the useful life of the cell.

(b) Desiccated cells to which water must be added before the cell is put into service may be included under these specifications.

## 2. TYPES OF CELLS.

The following types of dry cells will be considered in these specifications:

- (a) Telephone or light-service cells.
- (b) General purpose cells.
- (c) Ignition or heavy-service cells.
- (d) Flash-light cells and batteries.
- (e) Assembled batteries, exclusive of class (d).
- (f) Desiccated cells and other similar cells to which water must be added.
- (g) "B" batteries for radio service.

## 3. SIZES OF CELLS.

(a) STANDARD SIZES, IGNITION, TELEPHONE, AND SIMILAR CELLS, CYLINDRICAL FORM.—These dimensions are for the zinc container of the cell and are to be measured on the cell without the carton.

TABLE 1.

Diameter.	Height.	Diameter.	Height.
Inches.	Inches.	cm	cm
$1\frac{1}{4}$	4	4	10
$2\frac{1}{2}$	6	6.5	15

Deviations shall not exceed  $\frac{1}{8}$  inch in diameter and  $\frac{1}{8}$  inch in height from the dimensions as given in inches. The cells are to be of the flush-top type. Terminals shall not add more than  $\frac{5}{8}$  inch (1.6 cm) to the height of the cells as given above. The maximum diameter of the cells measured over the carton shall not exceed the diameter as given above by more than  $\frac{1}{8}$  inch (3 mm).

(b) STANDARD SIZES, FLASH-LIGHT CELLS, CYLINDRICAL FORM.—These dimensions are for the zinc container of the cell.

TABLE 2.

Diameter.	Height.	Diameter.	Height.
Inches.	Inches.	cm	cm
$\frac{2}{3}$	$1\frac{1}{8}$	1.6	4.8
$\frac{3}{4}$	$2\frac{1}{8}$	1.9	5.4
$\frac{1}{2}$	$1\frac{1}{4}$	2.4	4.6
$1\frac{1}{4}$	$2\frac{3}{4}$	3.2	5.7
$1\frac{1}{2}$	$2\frac{5}{8}$	3.2	7.3

a Provisionally included in table.

Deviations from these dimensions, as given in inches, shall not exceed  $\frac{1}{8}$  inch in height or  $\frac{1}{8}$  inch in diameter. The height, including cap on carbon rod, shall not exceed the height given in Table 2 by more than  $\frac{1}{8}$  inch (3 mm).

(c) FLASH-LIGHT BATTERIES, STANDARD SIZES.—These batteries contain cells of standard sizes as given above. The batteries are listed in the following table. Deviations from these dimensions, as given in inches, shall not exceed  $\frac{1}{8}$  inch in height per cell, or  $\frac{1}{8}$  inch in diameter for tubular batteries; nor  $\frac{1}{8}$  inch in height or  $\frac{1}{8}$  inch per cell in width, and  $\frac{1}{8}$  inch in depth for flat or box batteries.

TABLE 3.

Kind.	No. of cells.	Size of cells.				Dimensions of battery.					
		Diam-eter.	Height.	Diam-eter.	Height.	Width or diam-eter.	Height.	Depth.	Width or diam-eter.	Height.	Depth.
		In.	In.	cm	cm	In.	In.	In.	cm	cm	cm
Unit cell.....	1	$1\frac{1}{4}$	$2\frac{1}{4}$	3.2	5.7	$1\frac{1}{4}$	$2\frac{1}{4}$	.....	3.3	5.9	.....
	1	$1\frac{1}{4}$	$1\frac{1}{4}$	2.4	4.6	1	$1\frac{1}{8}$	.....	2.5	4.8	.....
Tubular.....	3	$1\frac{1}{4}$	$2\frac{1}{4}$	3.2	5.7	$1\frac{1}{4}$	7	.....	3.3	17.8	.....
	2	$1\frac{1}{4}$	$2\frac{1}{4}$	3.2	5.7	$1\frac{1}{4}$	$4\frac{1}{4}$	.....	3.3	11.9	.....
	2	$1\frac{1}{4}$	$1\frac{1}{4}$	2.4	4.6	1	$3\frac{1}{4}$	.....	2.5	9.5	.....
Flat.....	a 3	$1\frac{1}{4}$	$2\frac{1}{4}$	1.9	5.4	$2\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{1}{4}$	6.2	6.3	2.1
	3	$1\frac{1}{4}$	$1\frac{1}{4}$	1.6	4.8	2	$2\frac{1}{4}$	$1\frac{1}{4}$	5.1	5.7	1.75
	2	$1\frac{1}{4}$	$1\frac{1}{4}$	1.6	4.8	$1\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{1}{4}$	3.3	5.7	1.75
Box.....	3	$1\frac{1}{4}$	$2\frac{1}{4}$	3.2	7.3	$3\frac{1}{4}$	$3\frac{1}{4}$	$1\frac{1}{4}$	9.8	7.8	3.3

a Provisionally included in table.

(d) ASSEMBLED BATTERIES.—The individual cells in these batteries shall conform to these specifications, with the exception that the cartons may be omitted, other insulation between the cells being provided. The cells in these batteries are to be  $2\frac{1}{2}$  inches in diameter by 6 inches in height.

TABLE 4.—Standard Sizes of Assembled Batteries.

[These batteries contain No. 6 cells. The dimensions given are the maximum.]

Assembly.	Voltage.	Length.	Width.	Height.	Weight.	Length.	Width.	Height.	Weight.
	Volts.	Inches.	Inches.	Inches.	Pounds.	cm	cm	cm	kg
2 cells, single row.....	3	$5\frac{1}{4}$	$2\frac{1}{4}$	$7\frac{1}{2}$	5	13	7	19	2.3
4 cells, single row.....	6	$10\frac{1}{4}$	$2\frac{1}{4}$	$7\frac{1}{2}$	$10\frac{1}{2}$	27	7	19	4.8
4 cells, double row.....	6	$5\frac{1}{4}$	$5\frac{1}{4}$	$7\frac{1}{2}$	$10\frac{1}{2}$	13.7	13.7	19	4.8
5 cells, single row.....	$7\frac{1}{2}$	$13\frac{1}{4}$	$2\frac{1}{4}$	$7\frac{1}{2}$	13	33.7	7	19	5.9
5 cells, double row.....	$7\frac{1}{2}$	8	$5\frac{1}{4}$	$7\frac{1}{2}$	13	20.3	13.7	19	5.9
6 cells, double row.....	9	8	$5\frac{1}{4}$	$7\frac{1}{2}$	16	20.3	13.7	19	7.3

The height given is the maximum height over all. The body of the battery will be  $6\frac{1}{2}$  to 7 inches in height.

(e) STANDARD SIZES, "B" BATTERIES FOR RADIO SERVICE.—These batteries contain cells of standard sizes as shown in Table 5. The cells are to be connected in series.

TABLE 5.—"B" Batteries for Radio Service.

Assembly.	No. of cells.	Size of cells.				Dimensions of battery.					
		Diam-eter.	Height.	Diam-eter.	Height.	Length.	Height.	Width.	Length.	Height.	Width.
Rectangular box.....	15	Inches. $\frac{3}{8}$	Inches. $1\frac{1}{8}$	cm 1.6	cm 4.8	Inches. $3\frac{3}{8}$	Inches. $2\frac{1}{4}$	Inches. $2\frac{1}{4}$	cm 8.6	cm 6.5	cm 5.2
Rectangular box.....	15	$1\frac{1}{4}$	$2\frac{1}{4}$	3.2	5.7	$6\frac{1}{2}$	3	4	16.8	7.6	10.2

Deviations from these dimensions as given in inches shall not exceed the following:

Smaller battery,  $\frac{1}{8}$  inch in length, width, or height.

Larger battery,  $\frac{1}{8}$  inch in length,  $\frac{1}{8}$  inch in width or height.

#### 4. CARTON.

The individual cells, except those in assembled batteries, flash-light batteries, and radio batteries, shall be inclosed in a close-fitting carton of news, chip, or strawboard. Paraffined or waxed cartons may be required for special purposes. On the outside of the carton shall be printed the following information:

The trade name of the cell.

Its number or other designation of size.

The date of manufacture or the expiration of a guaranty period. (Optional: This may be on zinc container.)

The name of the manufacturer or such trade-mark as will identify the manufacturer.

Any necessary directions as in the case of desiccated cells.

#### 5. ZINC CAN.

The zinc can serves as a container for the cell and as the anode. It is to be made from smooth sheet zinc, free from flaws, blisters, and cracks.

#### 6. SEALING COMPOUND.

The sealing compound shall be an insulating material which shall not cold flow at a temperature of 45° C. (113° F.) during a static test of 24 hours' duration.

## 7. TERMINALS AND CELL CONNECTIONS.

(a) LARGE SINGLE CELLS (TABLE 1).—The terminals are to be of brass of the knurled nut and screw type (thread 8-32). Spring clips are to be furnished when specified. The terminals shall not be obstructed by the cardboard carton or protruding material of the seal.

(b) FLASH-LIGHT SINGLE CELLS (TABLE 2).—The brass cap on the carbon rod and the zinc bottom of the cell serve as the terminals.

(c) FLASH-LIGHT BATTERIES (TABLE 3).—*Tubular batteries.*—The cells in these batteries are of the flush-top type assembled end to end. The brass cap on carbon rod of the top cell is one terminal, the other terminal being the zinc bottom of the lowest cell.

*Flat batteries.*—The cells in these batteries are to be assembled side by side with soldered connections. The terminals of the batteries are to be of spring brass, soldered to the cells.

*Box batteries.*—The cells in these batteries are to be assembled side by side with soldered connections. The terminals of the batteries are to be of spring brass brought out from top of the battery on the same side  $2\frac{1}{2}$  inches apart from center to center.

(d) ASSEMBLED BATTERIES (TABLE 4).—The batteries are to have soldered connections between the individual cells. The terminals are to be brought through the top of case or sealing material to binding posts. The polarity of the terminals is to be marked.

(e) "B" BATTERIES FOR RADIO SERVICE (TABLE 5).—These batteries are to have soldered connections between the individual cells. The two end cells of the series are to be at diagonally opposite corners of the battery. The terminal leads of the battery are to consist of stranded copper conductor equivalent to No. 18 B. & S. gauge. The terminal wires are to be rubber-insulated, covered with single cotton braid. The positive lead is to have a red braid and the negative lead a black braid. The leads are to be 6 inches long to within one-half inch. The free ends of the leads shall be bared for a distance of one-half inch and the strands twisted and soldered together. The bared ends are to be insulated before shipment to prevent short circuits. The use of tinned copper conductors for the leads and the use of intermediate taps and the other forms of terminals are optional.

## 8. VOLTAGE.

The voltage of individual cells shall be not less than the values shown in Table 6 for the corresponding sizes of cells when measured with a voltmeter having a resistance of not less than 100 ohms per volt and having not less than 50 divisions per volt of its scale.

The voltage of batteries of two or more cells shall be not less than the product of the required minimum voltage per cell by the number of cells in the battery when measured with a voltmeter of equal quality having a range that provides at least 25 divisions for the nominal voltage which is to be measured.

TABLE 6.

Size of cell.		Minimum voltage.
Diameter.	Height.	
Inches.	Inches.	
2½	6	1.50
1½	4	1.50
1¼	2½	1.50
1¼	2¼	1.50
1¼	1¾	1.49
¾	2¼	1.48
¾	1¾	1.47

## 9. TESTS.

Details concerning the apparatus and methods used in making the various tests on dry cells and batteries covered by these specifications may be found in the current edition of Circular No. 79 of the Bureau of Standards on Electrical Characteristics and Testing of Dry Cells.

The size and kind of dry cell or the conditions of service will determine the kind of test to be applied. Cells are to be free from leaks during the period of test. The standard temperature for tests is 20° C. The tests ordinarily made are as follows:

(a) INTERMITTENT TESTS.—(1) *Light intermittent service*.—Three cells connected in series are discharged through 20-ohms resistance for 10 periods of 4 minutes each at hourly intervals during 6 days per week. On the remaining day every other discharge period is omitted. (There are 65 such discharge periods per week, or a total weekly service of 260 minutes.)

The following readings will be taken:

Initial open-circuit voltage of the battery.

Initial closed-circuit voltage of the battery.

The closed-circuit voltage at the end of a discharge, after 7 days, and every 7 days thereafter until the voltage falls below 3.5 volts, following which the readings are to be taken daily.

The test is considered finished when the working voltage of the battery has fallen below 2.8 volts. The service is reported as the total days on test to this cut-off voltage.

The test should be started so that the readings will be made on a day having 10 discharge periods and, if possible, the voltage reading should be taken at the end of the last discharge period for the day.

(2) *Heavy intermittent service.*—Four cells, connected in series, are discharged through  $10\frac{2}{3}$ -ohms resistance for two periods of 1 hour each daily; the discharge periods are to be not less than 6 hours apart.

The following readings will be taken:

Initial open-circuit voltage of the battery.

Initial closed-circuit or working voltage.

Closed-circuit voltage every other day thereafter at the end of the second period.

The test is considered completed when the closed-circuit voltage at the end of a period of discharge falls below 0.85 volt per cell. The test is reported as the hours of actual discharge to the cut-off voltage.

(3) *Flash-light test.*—The battery is discharged for 5-minute periods, at 24-hour intervals, through a resistance of 4 ohms for each cell in series in the battery. The following readings will be taken:

Initial open-circuit voltage of battery.

Initial closed-circuit voltage of battery.

Closed-circuit voltage of battery twice each week thereafter at the end of a discharge period.

The test is considered finished when the closed-circuit voltage at the end of a period of discharge falls below 0.5 volt per cell.

The result is reported as the total minutes of discharge to the cut-off voltage.

(b) **CONTINUOUS-DISCHARGE TEST.**—Intermittent tests are to be preferred to continuous tests. "B" batteries for radio service, however, are regularly tested by continuous discharge as specified.

(1) *10-ohm continuous test.*—Cells listed in Table 1 or batteries listed in Table 4 are discharged continuously through a resistance of 10 ohms per cell until the closed-circuit voltage of the battery has fallen below 0.75 volt per cell.

The following readings will be taken

Initial open-circuit voltage.

Initial closed-circuit voltage.

Readings daily of the closed-circuit voltage thereafter to the cut-off voltage.

The result is reported as the number of hours duration of the discharge.

(2) *2.75-ohm continuous test.*—This test is for the flash-light cells and batteries listed in Tables 2 and 3. These are discharged continuously through a resistance of 2.75 ohms per cell until the closed-circuit voltage of the battery has fallen below 0.50 volt per cell.

The following readings will be taken:

Initial open-circuit voltage.

Initial closed-circuit voltage.

Closed-circuit voltages at half hourly intervals for the larger sizes and 10-minute intervals for the smaller sizes until the voltage drops to 0.55 volt per cell, after which the readings are required twice as often.

The result of this test is reported as the number of minutes duration of the discharge.

(3) *5,000-ohm continuous test.*—This test is for "B" batteries for radio service (Table 5). These are discharged continuously through 5,000 ohms per battery of 15 cells until the closed-circuit voltage of the battery has fallen below 17 volts.

The following readings will be taken:

Initial open-circuit voltage.

Initial closed-circuit voltage.

Closed-circuit voltages twice daily for the small size; similar readings daily for the large size.

The result of this test is reported as number of hours of discharge to the cut-off voltage.

(c) **NOISE TEST FOR "B" BATTERIES.**—A radio head set of not less than 2,000 ohms resistance in series with 20,000 ohms is to be connected to the battery terminals. The battery shall not produce noise in the head set when the battery is jarred.

(d) **SHELF TESTS.**—Shelf tests shall consist of keeping the cells on open circuit at an even temperature of approximately 20° C. (68° F.) over a period of time, depending on the size of the cell, during which measurements of voltage and short-circuit current will be made, or tests of electrical capacity, which are designated as delayed service tests in Table 8.

The procedure for making delayed service tests follows the continuous test described above.

## 10. PERFORMANCE.

TABLE 7.—Intermittent Tests.

Size of cell.		Test.	Minimum required performance. <sup>1</sup>
Diameter.	Height.		
Inches.	Inches.		
2½	6	Heavy intermittent service.....	40 hours.
1½	4	Light intermittent service.....	60 days.
2½	6	Light intermittent service.....	160 days. <sup>2</sup>
¾	1¼	Flash light.....	100 minutes.
¾	2¼	Flash light.....	180 minutes.
¾	1¼	Flash light.....	250 minutes.
1¼	2¼	Flash light.....	600 minutes.
1¼	2¼	Flash light.....	

<sup>1</sup> Within one month from date of manufacture.<sup>2</sup> Allowance for depreciation after one month, 3 per cent per month.

TABLE 8.—Continuous and Delayed Service Tests.

Size of cell.		Test.	Minimum required performance.				
Diameter.	Height.		0 to 1 month.	3 months.	6 months.	9 months.	12 months.
Inches.	Inches.		Hours.	Hours.	Hours.	Hours.	Hours.
1½	4	10-ohm, single cell.....	60	56	54	47	.....
2½	6	10-ohm, single cell.....	185	180	175	165	155
¾	1¼	5,000 ohms, "B" batteries.....	75	71	68	63	53
1¼	2¼	5,000 ohms, "B" batteries.....	760	740	710	670	590
			Min-utes.	Min-utes.	Min-utes.	Min-utes.	Min-utes.
¾	1¼	2.75 ohms, flash-light batteries.....	55	49	44	.....	.....
¾	2¼	2.75 ohms, flash-light batteries.....	110	100	90	75	.....
¾	1¼	2.75 ohms, flash-light batteries.....	130	120	110	95	.....
1¼	2¼	2.75 ohms, flash-light batteries.....	500	470	445	420	375
1¼	2¼	2.75 ohms, flash-light batteries.....	600	560	540	510	450

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Standard  
Specification,  
No. 52.

DEPARTMENT OF COMMERCE.

U.S. BUREAU OF STANDARDS.

CIRCULAR OF THE BUREAU OF STANDARDS.

No. 140.

[March 26, 1923.]

UNITED STATES GOVERNMENT SPECIFICATION FOR  
WOOD SCREWS.

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION NO. 52.

This Specification was officially adopted by the Federal Specification Board, on February 1, 1923, for the use of the Departments and Independent Establishments of the Government in the purchase of wood screws.

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1. INTRODUCTION.

This specification summarizes the results of the standardization of wood screws by the manufacturers in cooperation with the Bureau of Standards and the technical committee on builders' hardware of the Federal Specifications Board. It has been officially adopted by the Federal Specifications Board for the use of all Departments and Independent Establishments of the Government in the purchase of wood screws.

The former difference of 0.013165 inch in diameter, used as a basis for the arithmetical progression of the numbering system,

has been discarded in favor of a difference of 0.013 inch (even) as established by the National Screw Thread Commission for machine screws. This provides interchangeability for the numbered sizes of machine screws and wood screws, in connection with articles that may be fastened either to metal or wood.

Flat, round, and oval head types are covered in the specification.

The numbered sizes of wood screws run consecutively from No. 0 (0.060 inch, or 1.5 mm) to No. 24 (0.372 inch, or 9.4 mm), omitting Nos. 13, 15, 17, 19, 21, 22, and 23.

The diameter is measured on the body of the screw under the head. The maximum tolerance in diameter permitted is +0.004 and -0.007 inch, or +0.1 and -0.2 mm.

The length of all screws is measured from the largest diameter of bearing surface of the head to the extreme end of the point measured parallel to axis of screw.

The plus tolerance in length is always zero. Tables of minus tolerance in length are given.

Screws are to be threaded approximately two-thirds of the nominal length.

The included angle of the head on flat and oval head screws is 82°.

The number of sizes of brass and steel screws manufactured as standard have been reduced from 555 to 291, a reduction of 47 per cent.

## 2. GENERAL SPECIFICATIONS.

**MATERIAL AND WORKMANSHIP.**—Screws shall be made of steel or brass, as specified, and shall be free from any defects which would affect their serviceability.

**POINTS.**—Standard screws shall be furnished with gimlet points. Cone and diamond pointed screws are special.

**TYPES.**—Screws shall be furnished in flat, round, or oval heads as ordered.

**MEASUREMENT OF LENGTHS.**—The length of all screws shall be measured from the largest diameter of bearing surface of the head to the extreme end of the point measured parallel to the axis of the screw.

**THREADED LENGTH.**—Screws shall be threaded approximately two-thirds of the nominal length.

**MEASUREMENT OF DIAMETERS.**—The diameter shall be measured on the body of the screw under the head.

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## Specification for Wood Screws.

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**TOLERANCE IN DIAMETER.**—The maximum tolerance in diameter permitted is  $+0.004$  and  $-0.007$  inch, or  $+0.1$  and  $-0.2$  mm.

**INCLUDED ANGLE.**—The included angle of the head on flat and oval head screws shall be  $82^{\circ}$ .

### 3. DIAMETERS AND NUMBERS.

The following numbers, diameters, and threads per inch are standard:

Number of screw.	Diameter. <sup>1</sup>		Threads per inch. <sup>2</sup>	Number of screw.	Diameter. <sup>1</sup>		Threads per inch. <sup>2</sup>
	Inch.	Milli-meters.			Inch.	Milli-meters.	
0.....	0.060	1.5	32	9.....	0.177	4.5	14
1.....	.073	1.9	28	10.....	.190	4.8	13
2.....	.086	2.2	26	11.....	.203	5.2	12
3.....	.099	2.5	24	12.....	.216	5.5	11
4.....	.112	2.8	22	14.....	.242	6.1	10
5.....	.125	3.2	20	16.....	.268	6.8	9
6.....	.138	3.5	18	18.....	.294	7.5	8
7.....	.151	3.8	16	20.....	.320	8.1	8
8.....	.164	4.2	15	24.....	.372	9.4	7

<sup>1</sup> Tolerance in diameter =  $+0.004$  inch, or  $+0.1$  mm.

<sup>2</sup> Tolerance in number of threads per inch =  $\pm 10$  per cent.

### 4. TOLERANCE IN LENGTH.

**FLAT AND OVAL HEAD SCREWS.**—The maximum tolerances permitted in the length of flat and oval head screws are as follows:

[Plus tolerance = 0.]

Nominal length.	Minus tolerance.	Nominal length.	Minus tolerance.
Inches.	Inch.	Inches.	Inch.
$\frac{1}{8}$	0.031	2	0.060
$\frac{1}{4}$	.033	$2\frac{1}{4}$	.064
$\frac{3}{8}$	.035	$2\frac{1}{2}$	.068
$\frac{1}{2}$	.037	$2\frac{3}{4}$	.072
$\frac{5}{8}$	.039	3	.076
$\frac{3}{4}$	.041	$3\frac{1}{2}$	.084
1	.043	4	.092
$1\frac{1}{4}$	.048	$4\frac{1}{4}$	.101
$1\frac{1}{2}$	.052	5	.109
$1\frac{3}{4}$	.056		

**ROUND HEAD SCREWS.**—The maximum tolerances permitted in the length of round head screws are as follows:

[Plus tolerance=0. Minus tolerances as given in body of table.]

Nominal length, inches.	Numbers.								
	0	1	2	3	4	5	6	7	8
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
$\frac{1}{8}$ .....	0.064	0.071	0.077	0.084	0.090	.....	.....	.....	.....
$\frac{1}{4}$ .....	.065	.073	.079	.086	.092	.099	0.105	0.112	0.118
$\frac{3}{8}$ .....	.....	.075	.081	.088	.094	.101	.107	.114	.120
$\frac{1}{2}$ .....	.....	.....	.083	.090	.096	.103	.109	.116	.122
$\frac{5}{8}$ .....	.....	.....	.085	.092	.098	.105	.111	.118	.124
$\frac{3}{4}$ .....	.....	.....	.....	.094	.100	.107	.113	.120	.126
1.....	.....	.....	.....	.096	.102	.109	.115	.122	.128
$1\frac{1}{4}$ .....	.....	.....	.....	.....	.106	.113	.119	.126	.132
$1\frac{1}{2}$ .....	.....	.....	.....	.....	.110	.117	.123	.130	.136
$1\frac{3}{4}$ .....	.....	.....	.....	.....	.....	.....	.127	.134	.140
2.....	.....	.....	.....	.....	.....	.....	.131	.138	.144
$2\frac{1}{4}$ .....	.....	.....	.....	.....	.....	.....	.135	.142	.148
$2\frac{1}{2}$ .....	.....	.....	.....	.....	.....	.....	.139	.146	.152

Nominal length, inches.	Numbers.								
	9	10	11	12	14	16	18	20	24
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
$\frac{1}{4}$ .....	0.127	0.133	.....	.....	.....	.....	.....	.....	.....
$\frac{3}{8}$ .....	.129	.135	0.142	0.148	.....	.....	.....	.....	.....
$\frac{1}{2}$ .....	.131	.137	.144	.150	0.163	.....	.....	.....	.....
$\frac{5}{8}$ .....	.133	.139	.146	.152	.165	.....	.....	.....	.....
1.....	.135	.141	.148	.154	.167	0.180	.....	.....	.....
$1\frac{1}{4}$ .....	.139	.145	.152	.158	.171	.184	0.198	.....	.....
$1\frac{1}{2}$ .....	.143	.149	.156	.162	.175	.188	.202	0.215	.....
$1\frac{3}{4}$ .....	.147	.153	.160	.166	.179	.192	.206	.219	.....
2.....	.151	.157	.164	.170	.183	.196	.210	.223	.....
$2\frac{1}{4}$ .....	.155	.161	.168	.174	.187	.200	.214	.227	.....
$2\frac{1}{2}$ .....	.159	.165	.172	.178	.191	.204	.218	.231	.....
$2\frac{3}{4}$ .....	.163	.169	.176	.182	.195	.208	.222	.235	.....
3.....	.167	.173	.180	.186	.199	.212	.226	.239	0.265
$3\frac{1}{2}$ .....	.....	.181	.188	.194	.207	.220	.234	.247	.273
4.....	.....	.....	.....	.202	.215	.228	.242	.255	.281
$4\frac{1}{2}$ .....	.....	.....	.....	.....	.223	.236	.250	.263	.289
5.....	.....	.....	.....	.....	.231	.244	.258	.271	.297

5. STANDARD SIZES, STEEL.

STEEL SCREWS.—The following sizes of steel screws are standard:

Lengths.		No. 0. Diam- eter, 0.060 in., 1.5 mm.	No. 1. Diam- eter, 0.073 in., 1.9 mm.	No. 2. Diam- eter, 0.086 in., 2.2 mm.	No. 3. Diam- eter, 0.099 in., 2.5 mm.	No. 4. Diam- eter, 0.112 in., 2.8 mm.	No. 5. Diam- eter, 0.125 in., 3.2 mm.	No. 6. Diam- eter, 0.138 in., 3.5 mm.	No. 7. Diam- eter, 0.151 in., 3.8 mm.	No. 8. Diam- eter, 0.164 in., 4.2 mm.
Inches.	Milli- meters.									
3/8	6.4	✓	✓	✓	✓	✓				
7/16	9.5	✓	✓	✓	✓	✓	✓	✓	✓	✓
1/2	12.7		✓	✓	✓	✓	✓	✓	✓	✓
5/8	15.9			✓	✓	✓	✓	✓	✓	✓
3/4	19.1			✓	✓	✓	✓	✓	✓	✓
7/8	22.2				✓	✓	✓	✓	✓	✓
1	25.4					✓	✓	✓	✓	✓
1 1/8	31.8					✓	✓	✓	✓	✓
1 1/4	38.1					✓	✓	✓	✓	✓
1 3/8	44.5							✓	✓	✓
2	50.8							✓	✓	✓
2 1/4	57.2							✓	✓	✓
2 1/2	63.5								✓	✓
2 3/4	69.9									✓
3	76.2									✓

Lengths.		No. 9. Diam- eter, 0.177 in., 4.5 mm.	No. 10. Diam- eter, 0.190 in., 4.8 mm.	No. 11. Diam- eter, 0.203 in., 5.2 mm.	No. 12. Diam- eter, 0.216 in., 5.5 mm.	No. 14. Diam- eter, 0.242 in., 6.1 mm.	No. 16. Diam- eter, 0.268 in., 6.8 mm.	No. 18. Diam- eter, 0.294 in., 7.5 mm.	No. 20. Diam- eter, 0.320 in., 8.1 mm.	No. 24. Diam- eter, 0.372 in., 9.4 mm.
Inches.	Milli- meters.									
1 1/2	12.7	✓	✓							
5/8	15.9	✓	✓	✓	✓					
3/4	19.1	✓	✓	✓	✓	✓				
7/8	22.2	✓	✓	✓	✓	✓				
1	25.4	✓	✓	✓	✓	✓	✓			
1 1/8	31.8	✓	✓	✓	✓	✓	✓	✓		
1 1/4	38.1	✓	✓	✓	✓	✓	✓	✓	✓	
1 3/8	44.5	✓	✓	✓	✓	✓	✓	✓		
2	50.8	✓	✓	✓	✓	✓	✓	✓	✓	
2 1/4	57.2	✓	✓	✓	✓	✓	✓	✓	✓	
2 1/2	63.5	✓	✓	✓	✓	✓	✓	✓	✓	
2 3/4	69.9	✓	✓	✓	✓	✓	✓	✓	✓	
3	76.2	✓	✓	✓	✓	✓	✓	✓	✓	✓
3 1/2	88.9		✓	✓	✓	✓	✓	✓	✓	✓
4	101.6				✓	✓	✓	✓	✓	✓
4 1/2	114.3					✓	✓	✓	✓	✓
5	127.0					✓	✓	✓	✓	✓

## 6. STANDARD SIZES, BRASS.

BRASS SCREWS.—The following sizes of brass screws are standard:

Lengths.		No. 0. Diam- eter, 0.060 in., 1.5 mm.	No. 1. Diam- eter, 0.073 in., 1.9 mm.	No. 2. Diam- eter, 0.086 in., 2.2 mm.	No. 3. Diam- eter, 0.099 in., 2.5 mm.	No. 4. Diam- eter, 0.112 in., 2.8 mm.	No. 5. Diam- eter, 0.125 in., 3.2 mm.	No. 6. Diam- eter, 0.138 in., 3.5 mm.	No. 7. Diam- eter, 0.151 in., 3.8 mm.
Inches.	Milli- meters.								
$\frac{1}{8}$ .....	6.4	✓	✓	✓	✓	✓			
$\frac{1}{4}$ .....	9.5	✓	✓	✓	✓	✓			
$\frac{3}{8}$ .....	12.7			✓	✓	✓	✓		
$\frac{1}{2}$ .....	15.9			✓	✓	✓	✓	✓	
$\frac{5}{8}$ .....	19.1			✓	✓	✓	✓	✓	✓
$\frac{3}{4}$ .....	22.2					✓	✓	✓	✓
1.....	25.4					✓	✓	✓	✓
$1\frac{1}{4}$ .....	31.8							✓	✓
$1\frac{1}{2}$ .....	38.1							✓	✓

Lengths.		No. 8. Diam- eter, 0.164 in., 4.2 mm.	No. 9. Diam- eter, 0.177 in., 4.5 mm.	No. 10. Diam- eter, 0.190 in., 4.8 mm.	No. 11. Diam- eter, 0.203 in., 5.2 mm.	No. 12. Diam- eter, 0.216 in., 5.5 mm.	No. 14. Diam- eter, 0.242 in., 6.1 mm.	No. 16. Diam- eter, 0.268 in., 6.8 mm.	No. 18. Diam- eter, 0.294 in., 7.5 mm.
Inches.	Milli- meters.								
$\frac{1}{8}$ .....	12.7	✓							
$\frac{1}{4}$ .....	15.9	✓	✓	✓					
$\frac{3}{8}$ .....	19.1	✓	✓	✓	✓				
$\frac{1}{2}$ .....	22.2	✓	✓	✓	✓	✓			
1.....	25.4	✓	✓	✓	✓	✓	✓		
$1\frac{1}{4}$ .....	31.8	✓	✓	✓	✓	✓	✓		
$1\frac{1}{2}$ .....	38.1	✓	✓	✓	✓	✓	✓		
$1\frac{3}{4}$ .....	44.5	✓	✓	✓	✓	✓	✓		
2.....	50.8	✓	✓	✓	✓	✓	✓	✓	✓
$2\frac{1}{4}$ .....	57.2			✓	✓	✓	✓	✓	✓
$2\frac{1}{2}$ .....	63.5			✓	✓	✓	✓	✓	✓
3.....	76.2					✓	✓	✓	✓
$3\frac{1}{2}$ .....	88.9					✓	✓	✓	✓

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**CIRCULAR**  
OF THE  
**BUREAU OF STANDARDS**

**No. 141**

**DESCRIPTION AND OPERATION  
OF AN AUDIO-FREQUENCY AMPLIFIER UNIT FOR  
SIMPLE RADIO RECEIVING OUTFITS**

**MARCH 24, 1923**



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## DESCRIPTION AND OPERATION OF AN AUDIO-FREQUENCY AMPLIFIER UNIT FOR SIMPLE RADIO RECEIVING OUTFITS.

### ABSTRACT.

This is the fifth circular in a series of descriptions of very simple radio receiving outfits. In Circular No. 133 an electron-tube detector unit to be used in conjunction with the single-circuit set (Circular No. 120) or with the two-circuit set (Circular No. 121) is described. This circular describes an audio-frequency amplifier unit, one or two of which may be used with the apparatus just mentioned, to increase the receiving radius of the station, as well as the volume of sound in the telephone receivers. The amplifier unit (or two of them) may be used with the receiving sets either exactly as described in Circulars Nos. 120 and 121, or with the crystal detector replaced by the electron-tube detector unit.

A suitable antenna is described in Circular No. 120, and auxiliary condensers and a loading coil are described in Circular No. 137. One of these condensers is used in the antenna circuit so that the receiving set may be more easily tuned to wave lengths below 300 meters (hereafter abbreviated m; the other condenser will somewhat improve the reception from spark stations. The loading coil is not an essential part of the receiving set, unless one desires to receive stations transmitting on wave lengths up to 3,000 m (wave frequencies down to 100 kilocycles per second).

The cost of the materials for a single amplifier unit described in this circular may be between \$13 and \$20, including an electron tube. If a storage battery and "B" battery are not already at hand these will add \$17 to \$25 to the cost.

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### I. INTRODUCTION.<sup>1</sup>

Many radio receiving sets include either a radio-frequency or an audio-frequency amplifier. A radio-frequency amplifier amplifies

<sup>1</sup> This is the fifth of a series of circulars describing very simple radio receiving equipment which were originally prepared for the Boys and Girls' Radio Clubs of the States Relations Service, Department of Agriculture, and are now obtainable only from the Superintendent of Documents, Government Printing Office, Washington, D. C., at the prices named.

Bureau of Standards Circular No. 120, Construction and Operation of a Simple Homemade Radio Receiving Outfit. Price, 5 cents. (Formerly Letter Circular 43.)

Bureau of Standards Circular No. 121, Construction and Operation of a Two-Circuit Radio Receiving Equipment with Crystal Detector. Price, 5 cents. (Formerly Letter Circular 44.)

Bureau of Standards Circular No. 133, Description and Operation of an Electron-Tube Detector Unit for Simple Radio Receiving Outfits. Price, 10 cents. (Formerly Letter Circular 48.)

Bureau of Standards Circular No. 137, Auxiliary Condensers and Loading Coil Used with Simple Homemade Radio Receiving Outfits. Price, 10 cents. (Formerly Letter Circulars 46 and 47.)

the radio-frequency signal before it is detected (rectified) by the crystal or electron-tube detector, while an audio-frequency amplifier amplifies the rectified signal after it leaves the crystal or electron-tube detector. The essential parts of either type of amplifier are the amplifier transformer and the electron tube. For an explanation of the principles of amplifiers, reference may be made to the book, *The Principles Underlying Radio Communication* (pp. 479-488), or to one of various books of which a list may be found in Bureau of Standards Circular No. 122, *Sources of Elementary Radio Information*.

This pamphlet describes an audio-frequency amplifier unit; that is, an amplifier employing a single electron tube. One or more such units is used with the single-circuit radio receiving set described in Bureau of Standards Circular No. 120, or with the two-circuit radio receiving set described in Bureau of Standards Circular No. 121, or with any other tuning device equipped with a detector. The detector may be either a crystal detector or an electron-tube detector similar to the one described in Bureau of Standards Circular No. 133.

The amplifier unit is used by connecting it to the receiving set in place of the telephone receivers and then connecting the telephone receivers to the output of the amplifier.

The audio-frequency amplifier unit is added to the tuner and detector so that the radio power received by the antenna may be transformed into sound in greater volume than would be possible by the use of a crystal or electron-tube detector alone. The use of such an audio-frequency amplifier unit increases the receiving radius of the outfits described in previous pamphlets of the series approximately 50 per cent. Still greater receiving radius may be obtained by adding another amplifier unit just like the first one. It is usually not practical to use more than two stages of audio-frequency amplification; that is, two audio-frequency amplifier units.

One of these amplifier units added to a regenerative receiving set <sup>2</sup> increases the volume of sound in the telephone receivers.

Since a circuit, including a crystal detector or simple electron-tube detector, will not make continuous wave <sup>3</sup> signals audible in

---

<sup>2</sup> See p. 487 of the book, *The Principles Underlying Radio Communication*, Signal Corps Radio Communication Pamphlet No. 40. This is a bound volume of over 600 pages, and is obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price, \$1 per copy. Regenerative apparatus is also described in various other publications listed in Bureau of Standards Circular No. 122, *Sources of Elementary Radio Information*, obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price, 5 cents.

<sup>3</sup> See pp. 431 and 501 of the book, *The Principles Underlying Radio Communication*.

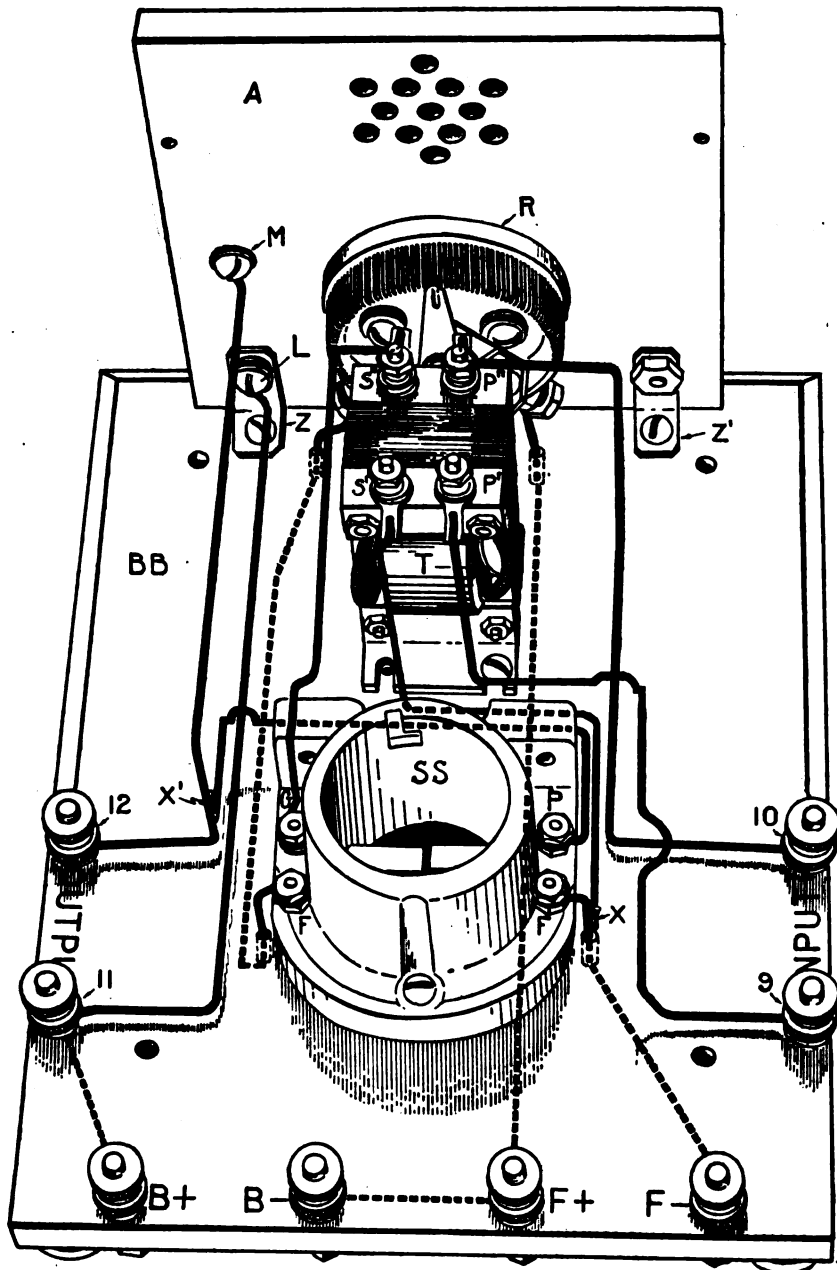


FIG. 1.—Diagram showing location of parts and wiring of electron-tube amplifier unit.

the telephone receivers, the addition of an audio-frequency amplifier to these circuits will not accomplish this result.

The cost of this audio-frequency amplifier unit, complete with an electron tube, is between \$13 and \$21. This does not include the cost of batteries. If an electron-tube detector is used in the receiving set, the same batteries are used for the amplifier unit. If, however, a storage battery for lighting the tube filament is not already available, this item will add from \$15 to \$22 to the estimate; and, if dry batteries are not already available, the addition of two dry batteries for supplying voltage to the plate of the tube will add from \$2 to \$3 to this estimate. The cost of the tuner, crystal detector, telephone receivers, and antenna equipment, which are usually used with this amplifier and which is itemized in Bureau of Standards Circulars Nos. 120 and 121, is between \$11 and \$23. If the electron-tube detector unit described in Bureau of Standards Letter Circular 48 or Circular No. 133 is used in place of the crystal detector, the cost of the complete equipment is increased by an amount varying between \$7 and \$13.70.

This publication describes simple apparatus of satisfactory performance, without reference to the possible existence of any patents which might cover parts of the apparatus. Apparatus, in general, similar to that described can be purchased from responsible manufacturers, whose announcements can be found in current radio periodicals.

## **II. ESSENTIAL PARTS OF COMPLETE RADIO RECEIVING STATION.**

A complete radio receiving station comprises:

**ANTENNA, LIGHTNING SWITCH, GROUND CONNECTIONS, AND TELEPHONE RECEIVERS.**—These are described in Bureau of Standards Circular No. 120.

**TUNING DEVICE.**—This is either the tuning coil described in Bureau of Standards Circular No. 120, or the two-circuit coupler and variable air condenser described in Bureau of Standards Circular No. 121, or any commercial tuning device which covers the required wave-frequency range.

**DETECTOR.**—This is either the crystal detector arranged as shown in Bureau of Standards Circulars Nos. 120 and 121, the electron-tube detector unit as described in Bureau of Standards Letter Circular 48 or Circular No. 133, or some satisfactory commercial electron-tube detector unit.

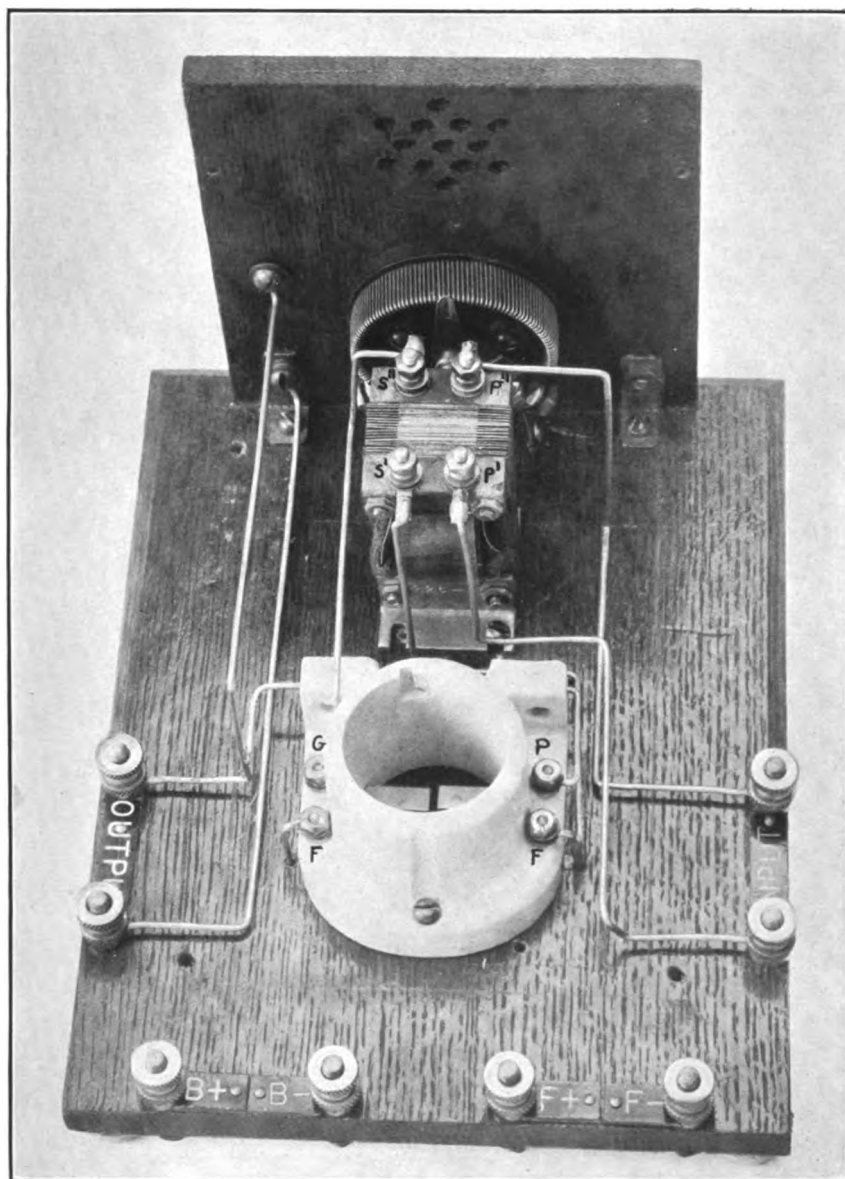


FIG. 2.—Assembled audio-frequency amplifier unit.



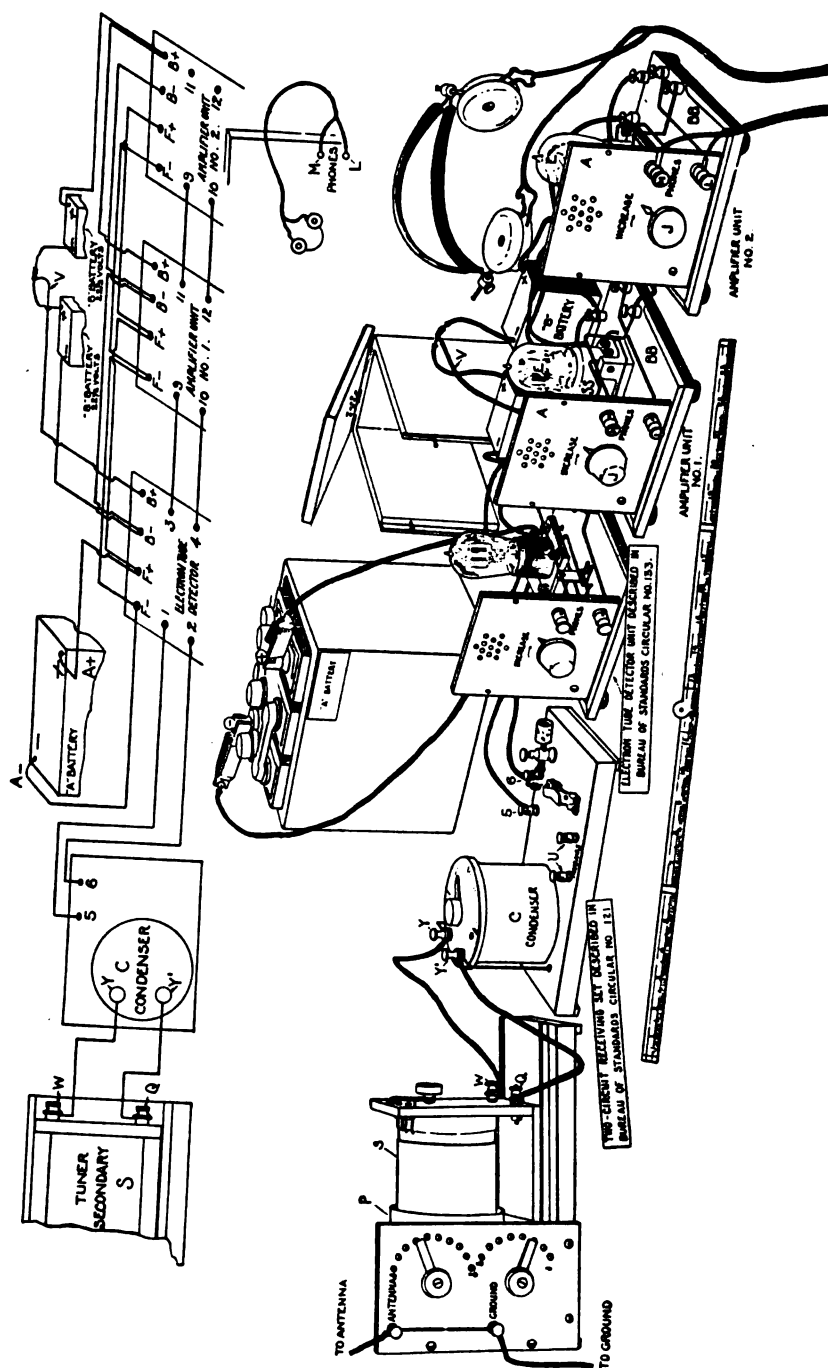


FIG. 3.—Method of connecting two-circuit receiving set, filament battery, plate battery, telephone receivers, and two audio-frequency amplifier units, ready for use.

**AUDIO-FREQUENCY AMPLIFIER UNIT (FIGS. 1, 2, AND 3).**—The audio-frequency amplifier unit is composed of a baseboard *BB* and an upright panel *A*. On the baseboard *BB* is mounted an electron-tube socket *SS*, an audio-frequency amplifier transformer *T*, and eight binding posts. On the upright panel *A* is mounted a filament rheostat *R* (the adjusting knob *J* is shown in Fig. 3) and two telephone-receiver binding posts *L* and *M*. The photograph (Fig. 2) shows the arrangement of these parts. This circular tells how the various parts are assembled on the baseboard and panel. No description is given of the construction of any of the parts.

**ACCESSORIES.**—Under the heading of accessories may be listed a six-volt storage battery ("A" battery) having an ampere-hour capacity of about 60, used for lighting the electron-tube filament, a 45-volt dry battery ("B" battery) for supplying the electron-tube plate voltage, binding posts, stiff copper wire (tinned wire is usually preferred), wood boards for the baseboard and upright panel, two brass angle braces for supporting the upright panel, miscellaneous wood screws, and suitable stain and varnish. A composition insulating material panel is sometimes substituted for the wood panel and the amplifier unit inclosed in a wood cabinet with a hinged cover. When the cabinet is added the eight baseboard binding posts are left exposed.

### III. DESCRIPTION OF PARTS.

**BASEBOARD (*BB*, FIGS. 1 AND 3).**—The base *BB* is any kind of dry, well-seasoned wood about  $6\frac{1}{4}$  inches by  $8\frac{1}{4}$  inches by  $\frac{1}{2}$  inch thick. Eight holes are drilled through the base in which the binding posts are fastened. The binding posts are spaced so that they present a neat appearance or according to the dimensions given in Figure 3, Bureau of Standards Letter Circular 48 or Circular No. 133. The baseboard is arranged so that the three remaining sides and a hinged cover may be added without changing the positions of the binding posts. Under each of the four corners of the baseboard *BB* rubber or wood feet are fastened in order that the binding-post heads and wiring on the under side of the baseboard will be protected.

**UPRIGHT PANEL (*A*, FIGS. 1 AND 3).**—Panel *A* is any suitable dry, seasoned wood about  $4\frac{1}{2}$  inches by 5 inches by  $\frac{3}{8}$  inch thick. In Figure 1 a back view of the panel is shown which brings the two holes for the telephone receiver binding posts *L* and *M* in the

lower left corner. (If the panel is viewed from the front these two holes will be at the lower right corner.) This panel is made to present a good appearance, it being the front panel. Four holes are drilled in panel *A*, one for the bolt which fastens the panel to the brace (see *Z'*, Fig. 1), two for the telephone-receiver binding posts *L* and *M* (Figs. 1 and 3), and one for the shaft of the filament rheostat *R* (see Fig. 1). The exact location and diameter of the hole for the rheostat shaft is determined from the rheostat itself. It is drilled so that the rheostat occupies as low a position as possible, allowing room enough to do the necessary wiring. Satisfactory upright panel measurements are given in Figure 4 of Bureau of Standards Letter Circular 48 or Circular No. 133.

**ELECTRON TUBE (*E*, FIG. 3).**—The electron tube is a commercially available tube generally called an amplifier tube or "hard" tube. The several parts of an electron tube (sometimes called a vacuum tube) are described in chapter 6, *The Principles Underlying Radio Communication*.

**ELECTRON-TUBE SOCKET (*SS*, FIGS. 1 AND 3).**—The electron-tube socket is one of the various commercially available types.

**AUDIO-FREQUENCY AMPLIFIER TRANSFORMER (*T*, FIG. 1).**—The audio-frequency amplifier transformer is one of the various commercially available types.

**BINDING POSTS.**—The binding posts used on the baseboard are  $\frac{1}{8}$  or  $\frac{3}{16}$  brass machine screws, each equipped with two nuts and two washers, if regular binding posts are not used. The telephone-receiver binding posts, *L* and *M* (Figs. 1 and 3), are of the set-screw type to admit the tips of the telephone-receiver cords.

**FILAMENT RHEOSTAT (*R*, FIG. 1).**—The filament rheostat is one of the various commercially available types designed for panel mounting and having a neat-appearing knob and pointer. The rheostat has a resistance of about 7 ohms and a current-carrying capacity of about  $1\frac{1}{2}$  amperes.

**ACCESSORIES.**—The accessory batteries are commercial articles. The purchaser of the six-volt storage battery ("A" battery) for lighting the filaments should get full instructions from the dealer for testing and recharging the battery. The 45-volt dry battery ("B" battery) usually used for the plate circuit can not be recharged. The normal life of a dry battery of reliable manufacture is about six months. Storage batteries for use as "B" batteries are available. Their first cost is greater than that of dry batteries, but they may be recharged.

Satisfactory dimensions for the brass angle braces are given in Figure 1, Bureau of Standards Letter Circular No. 48 or Circular No. 133.

#### IV. ASSEMBLY AND WIRING.

**WOOD FINISH.**—It is essential that the wood be protected from moisture. The wood is first dried, and then finished with stain and varnish; a good grade of varnish, preferably insulating varnish, is used. Shellac or other alcohol dissolved resins are not used. This method of wood finishing is found more satisfactory than treating with paraffin, as described in Bureau of Standards Circular No. 120. The exact method of drying and finishing wood depends upon the condition of the wood itself. The wood is usually placed in a warm oven for an hour or so to insure more or less complete drying. The use of lampblack or carbon pigment stains is avoided, and the stain and varnish is thoroughly dried before the apparatus is mounted on the wood baseboard and panel.

**BASEBOARD (FIG. 1).**—The eight brass machine screws or binding posts are put in the holes already drilled in the baseboard. If machine screws are used, the heads are put on the underside of the baseboard with a brass washer between the head and the baseboard. A brass washer and two nuts are then fastened to each screw, on the upper side of the baseboard, with the washer next to the baseboard.

The tube socket *SS* and the transformer *T* are next screwed to the baseboard. The exact location of these parts varies according to the particular type used. One can get an idea of the relative position of the several parts from Figure 2. The tube socket *SS* is mounted so that the two terminals marked *G* and *P* (Fig. 1) are nearest the upright panel. Wood blocks are put under the socket *SS* when necessary, so that the four terminals of the socket do not touch the wood baseboard. This is done by cutting off two round wood blocks just long enough to raise the socket terminals clear of the base, and mounting them so that the screws which hold the socket to the baseboard will pass through holes in the centers of the blocks.

After the socket *SS* and the transformer *T* are mounted, the parts are wired. No. 14 bare (preferably tinned) copper wire is used in wiring. This makes the connections stiff and self-supporting. This wire is ordinarily furnished in rolls and is straightened before being used. This is accomplished by clamping or otherwise fastening one end of the wire solidly and pulling

on the other end just hard enough to stretch the wire slightly. All wires are run as direct as possible consistent with good spacing and neat appearance, and all bends are made at right angles. When a wire is attached to a binding post, a loop or eye is formed on the end of the wire and the wire at the eye flattened with a hammer. This gives more contact surface. Special lugs are sometimes soldered to the ends of the wires before the connections are made.

A small hole is drilled through the baseboard near each of the tube-socket terminals marked *F* (see Fig. 1). A short piece of wire is fastened to the right-socket terminal marked *F* and is then led through the small hole in the baseboard to the underside of the baseboard. The same wire is led to the underside of the binding post marked *F*, and fastened between the machine-screw head and washer underneath the baseboard. All wires which are run on the underside of the baseboard or are hidden by parts of the apparatus are shown by dotted lines. A wire is soldered (at *X*) to the wire leading from the right-socket terminal marked *F* just above the baseboard and led to the secondary terminal *S'* of the transformer *T* and soldered or otherwise fastened thereto. This wire is shown as part solid and part dotted. The wires do not touch the wood boards except at the terminals and where the wires pass through holes in the baseboard. The wires may be raised more or less to accomplish this. Another wire is soldered to a primary terminal *P'*, of the transformer and led to the "input" binding post No. 9. Humps or bends are shown in this and other wires to indicate that the wires cross but do not touch.

A wire is soldered to the other primary terminal *P''* of the transformer *T* and goes from there to the other "input" binding post No. 10. A similar wire reaches from the other secondary terminal *S''* of the transformer to the electron-tube socket terminal marked *G*. The secondary transformer terminal which connects to the terminal *G* of the electron-tube socket is that terminal which is internally connected to the outside end of the secondary coil of the transformer. This is sometimes determined by inspection; in other cases it is necessary to try out the completed amplifier unit, as described under "Operation." If good results are not obtained, the wire leading from *G* to *S''* is removed from *S''* and connected to *S'*, and the wire leading from *X* to *S'* is removed from *S'* and connected to *S''*.

A wire connects the binding post  $B +$  and the "output" binding post No. 11, on the under side of the baseboard. The remainder of the wiring is left until the upright panel is assembled and fastened to the baseboard. The procedure in making soldered connections is given in Bureau of Standards Letter Circular 48 or Circular No. 133.

UPRIGHT PANEL (*A*, FIG. 1).—The filament rheostat  $R$  is mounted on the upright panel  $A$  so that the two terminals will be in a convenient position for wiring. Two binding posts of the set-screw type,  $L$  and  $M$  (Figs. 1 and 3), are inserted in their proper holes, and the upright panel mounted in position by bolting it to the two brass angle pieces ( $Z$  and  $Z'$ ) shown in Figure 1. One of the telephone-receiver binding posts  $L$  serves as a bolt. Two small holes are drilled through the baseboard near the two terminals of the filament rheostat  $R$ . A wire is run from the "output" binding post No. 11 (Fig. 1) along the upper side of the baseboard to the back of the telephone-receiver binding post marked  $L$ . A wire is fastened to the other "output" binding post (No. 12) and led to the rear of the upper telephone-receiver binding post  $M$ . A wire is fastened to the electron-tube socket terminal  $P$  and led to some convenient point  $X'$  on the wire leading from binding post No. 12 to  $M$ . The two wires are soldered together at this point.

A wire is run from one of the filament rheostat binding posts through the hole in the baseboard and thence along the under side of the baseboard to the binding post marked  $F +$  and is continued from  $F +$ , still underneath the baseboard, to the binding post marked  $B -$ . This wire is shown in Figure 1 by a dotted line. Likewise a wire is run from the other rheostat binding post, underneath the baseboard and up through the left hole in the baseboard at the rear of the electron-tube socket  $SS$  and connected to the left binding post marked  $F$ . This completes the assembling and wiring of the audio-frequency amplifier unit.

## V. CONNECTIONS.

If the two-circuit tuner and the electron-tube detector are used with the audio-frequency amplifier unit, the several parts are arranged as shown in Figure 3. Two amplifier units are shown, making a two-stage amplifier. If only one unit is used, the connections are correspondingly simpler. If a "hard" or amplifier tube is used in the electron-tube detector unit, the connection  $V$  from the "B" battery is not used, but instead the wire  $V$  is con-

nected to the binding post *B* + on the amplifier No. 1. Increasing the number of "B" batteries used to supply voltage to the plates of the amplifier tubes will usually increase the intensity or loudness of the amplified radio signals, but at the same time the quality of the tone will be impaired. The voltage should never be increased to as much as twice the rated plate voltage of the electron tube.

The two-circuit tuner and the tuning condenser *C* (shown at the left) are described in Bureau of Standards Circular No. 121. The location and wiring of the two additional binding posts, 5 and 6, on the baseboard supporting the tuning condenser *C*, are given in Figure 6, Bureau of Standards Letter Circular 48 or Circular No. 133.

If the single-circuit tuner and electron-tube detector are used with the audio-frequency amplifier, the arrangement of the parts is also similar to that shown in Figure 3, except that the single-circuit tuner (as described in Bureau of Standards Circular No. 120 and altered in Fig. 5, Bureau of Standards Letter Circular 48 or Circular No. 133) replaces the two-circuit receiving set. The binding posts, 5 and 6, on the single-circuit tuner are connected to the electron-tube detector binding posts Nos. 1 and 2, respectively.

If the electron-tube detector is not available, one method of connection is to use the audio-frequency amplifier with the single-circuit or the two-circuit radio receiving set shown in Bureau of Standards Letter Circular No. 48 or Circular No. 133. In this case the telephone receiver binding posts (*X*, Fig. 5, or *U*, Fig. 6, Letter Circular 48 or Circular No. 133) are connected directly to the amplifier "input" binding posts Nos. 9 and 10. The connections to the "A" and "B" batteries are the same as shown in Figure 3 of this circular, except that the wiring to the electron-tube detector is omitted. Great care is taken to see that the "B" or plate battery is not connected to the binding posts marked *F* + and *F* -. The voltage of this battery is too high for the electron-tube filament and will burn it out.

The antenna and ground wires are connected, as described in Bureau of Standards Circular No. 120 and as shown in Figure 3.

To SUMMARIZE.—If the audio-frequency amplifier unit is used (1) with the two-circuit tuner and tuning condenser (Circular No. 121) and electron-tube detector (Letter Circular 48 or Circular No. 133), the connections are: *W* to *Y*, *Q* to *Y'*, 5 to 1,

6 to 2,  $A -$  to  $F -$  to  $F -$ ,  $A +$  to  $F +$  to  $F +$ , "B" battery - (black) to  $B -$  to  $B -$ , "B" battery connection  $F$  to detector  $B +$ , "B" battery + (red) to amplifier  $B +$ , 3 to 9, 4 to 10, 11 to 9, 12 to 10, and the telephone receivers to  $L$  and  $M$ ; (2) with the single-circuit tuner (Circular No. 120) and electron-tube detector, the connections are: 5 to 1, 6 to 2, and so on as given in (1); (3) with the two-circuit receiving set when the crystal detector replaces the electron-tube detector, the connections are:  $W$  to  $Y$ ,  $Q$  to  $Y'$ ,  $U$  (right) to 9,  $U$  (left) to 10,  $A -$  to  $F -$ ,  $A +$  to  $F +$ , "B" battery - (black) to  $B -$ , "B" battery + (red) to  $B +$ , and the telephone receivers to  $L$  and  $M$ ; (4) with the single-circuit receiving set when the crystal detector replaces the electron-tube detector, the connections are:  $X$  (right) to 9,  $X$  (left) to 10, and so on as given in (3).

## VI. OPERATION.

The two filament rheostat knobs marked  $J$  (Fig. 3) on the two audio-frequency amplifier units, and also the filament rheostat knob on the electron-tube detector unit, are turned to the extreme left or to the "off" position. Two electron tubes marked  $E$  ("hard" or amplifier tubes) are inserted in the sockets of the amplifier units (Nos. 1 and 2), and a third electron tube (preferably a "soft" or gas tube) is inserted in the socket of the electron-tube detector unit. The three filament rheostat knobs are then turned to the right until the filaments of the electron tubes become lighted, the brilliancy depending upon the type of electron tubes used. When one of the telephone-receiver terminals is removed from its binding post (either  $L$  or  $M$ ) and again touched to the post, a sharp "click" in the telephone-receivers will be an approximate indication that the circuit is in working condition. If the test buzzer, as described in Bureau of Standards Circular No. 120, is available, it is attached by a flexible wire to the binding post  $W$  on the two-circuit tuner, or, if the single-circuit tuner is used, the test buzzer is attached to the binding post marked "Ground" to determine when the detector is in working condition.

The test buzzer is not at all necessary when the receiving set employs an electron tube for a detector, as the "settings" of the filament rheostats largely determine the operating condition of the receiving set after it has been tuned to the proper wave frequency (wave length). When a crystal detector is used in place of the electron-tube detector unit, a buzzer test is desirable to locate a sensitive point on the crystal.

When the crystal detector is not used the electron-tube detector unit is merely substituted for it as shown in Figure 3 and the tuning of the receiving circuit is the same as described in Bureau of Standards Circulars Nos. 120 and 121. When the signals from a desired transmitting station are heard as loud as possible by tuning, the intensity is sometimes improved by adjusting one or more of the knobs on the filament rheostats, so as to increase or decrease the filament current (current from the "A" battery). The knobs are kept in the positions of minimum filament currents without reducing the strength of the incoming signals.

If the electron-tube detector unit is equipped with a "soft" or "gas" tube, the voltage of the "B" battery is changed until the greatest signal intensity is obtained. This necessitates the use of a tapped "B" battery. This means that the wire *V* (Fig. 3), instead of connecting to the wire which connects the two "B" batteries, is provided with a clip which is connected to successive tapped terminals on one of the "B" batteries until the required voltage is obtained.

When two audio-frequency amplifier units are used a continuous "howl" is sometimes produced in the telephone receivers. In this case the wires leading to the "input" binding posts of one or both of the amplifier units are reversed; that is, binding post 3 is connected to binding post 10, and 4 to 9, and binding post 11 of amplifier No. 1 to binding post 10 of amplifier No. 2, and also 12 to 9.

In case the apparatus fails to operate the trouble may be attributed to a variety of causes. An inspection is first made of the various parts of the receiving equipment to determine if they are properly connected, special care being taken to see that the positive (+) and negative (-) terminals of the "A" battery are connected, respectively, to the binding posts marked *F* + and *F* -, and that the positive (+, red) and negative (-, black) terminals of the "B" battery are connected, respectively, to the binding posts marked *B* + and *B* -.

To determine if the various parts of the receiving circuit are in working condition the telephone receivers are removed from the "phone" binding posts on the amplifier unit and connected to the "phone" binding posts on the crystal-detector receiving set. The wires connecting to binding posts 5 and 6 (Fig. 3) are temporarily removed and the fine, coiled wire brought in contact with the crystal. The receiving set is then adjusted as described in

Bureau of Standards Circular Nos. 120 or 121. This furnishes a means of ascertaining if the tuner is in working condition, and also the crystal detector, although the latter is, of course, not used with the electron-tube detector and amplifier units unless the electron-tube detector unit is omitted.

The wires are now reconnected to the binding posts 5 and 6 and the telephone receivers are connected to the "phone" binding posts on the electron-tube detector unit. One of the wires which is connected to one of the "output" binding posts of the electron-tube detector unit is temporarily removed and tests made to determine if the electron-tube detector is in working condition.

The telephone receivers are next connected to the "phone" binding posts on amplifier No. 1, the wire reconnected to the "output" binding post of the electron-tube detector unit, and one of the wires disconnected from one of the "output" binding posts (11 or 12) of amplifier No. 1. Tests are then made to determine if amplifier No. 1 is in working condition.

The telephone receivers are then removed from amplifier No. 1 and attached to amplifier No. 2. The wire is reconnected to the "output" binding post of amplifier No. 1. The connections are now as shown in Figure 3.

If the crystal detector is used in place of the electron-tube detector unit the same general scheme of testing is followed.

## VII. APPROXIMATE COST OF PARTS.

The following list gives the cost of parts of one audio-frequency amplifier unit and the "A" and "B" batteries. It does not include the cost of the telephone receivers or of any of the other equipment used to make up the outfits described in the previous circulars of the series. Some of the parts are the same as listed in the electron-tube detector circular with some of the prices revised. If audio-frequency amplifier units are used with the electron-tube detector unit the same "A" and "B" batteries are used, except that if a single "B" battery is used with the electron-tube detector unit one additional "B" battery is required.

## Audio-Frequency Amplifier Unit.

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### Audio-frequency Amplifier Unit.

Electron-tube ("hard," amplifier) .....	\$6.50 to \$6.50
Electron-tube socket .....	.25 to 1.50
Filament rheostat .....	.50 to 2.50
Audio-frequency amplifier transformer .....	5.00 to 8.00
10 feet No. 14 bare tinned copper wire, about .....	.10 to .10
8 binding posts, broad contact type .....	.40 to 1.20
2 binding posts, set-screw type (for telephone cord tips) .....	.10 to .30
Miscellaneous wood screws, about .....	.10 to .10
Wood (hard, for base and panel) .....	
1 piece $8\frac{1}{4}$ by $6\frac{1}{4}$ by $\frac{1}{2}$ inches.	
1 piece 5 by $4\frac{1}{2}$ by $\frac{3}{4}$ inches.	
4 rubber feet, about .....	.10 to .10
Wood (for cover) .....	
2 pieces for sides, $7\frac{1}{4}$ by 5 by $\frac{1}{2}$ inches.	
1 piece for back, 5 by $3\frac{3}{4}$ by $\frac{1}{2}$ inches.	
1 piece for top, $7\frac{3}{4}$ by $5\frac{1}{4}$ by $\frac{1}{2}$ inches.	
2 hinges for top, $\frac{3}{4}$ inch .....	
Stain and varnish, solder, soldering flux .....	
	<u>13.05 to 20.30</u>
<b>Batteries:</b>	
"A" storage battery, 6-volt 60-ampere-hour .....	15.00 to 22.00
2 "B" batteries, 22½ volts each .....	2.00 to 3.00
	<u>17.00 to 25.00</u>
<b>Total</b> .....	30.05 to 45.30

## VIII. SUGGESTIONS TO STUDENT.

The person who desires to study the principles of operation of radio receiving sets more advanced than have been given in this series on very simple apparatus will find useful information in "The Principles Underlying Radio Communication," previously referred to, and in the periodicals and books listed in Bureau of Standards Circular No. 122, Sources of Elementary Radio Information. Both publications are obtainable from the Superintendent of Documents, Government Printing Office, the former at \$1 and the latter at 5 cents.

In textbooks and articles generally, the parts of radio apparatus are represented by conventional symbols. For the assistance of the student, Figure 4 of this pamphlet shows the more common symbols which are extensively used in diagrams of apparatus and circuits. One should be familiar with these in order to read circuit diagrams.

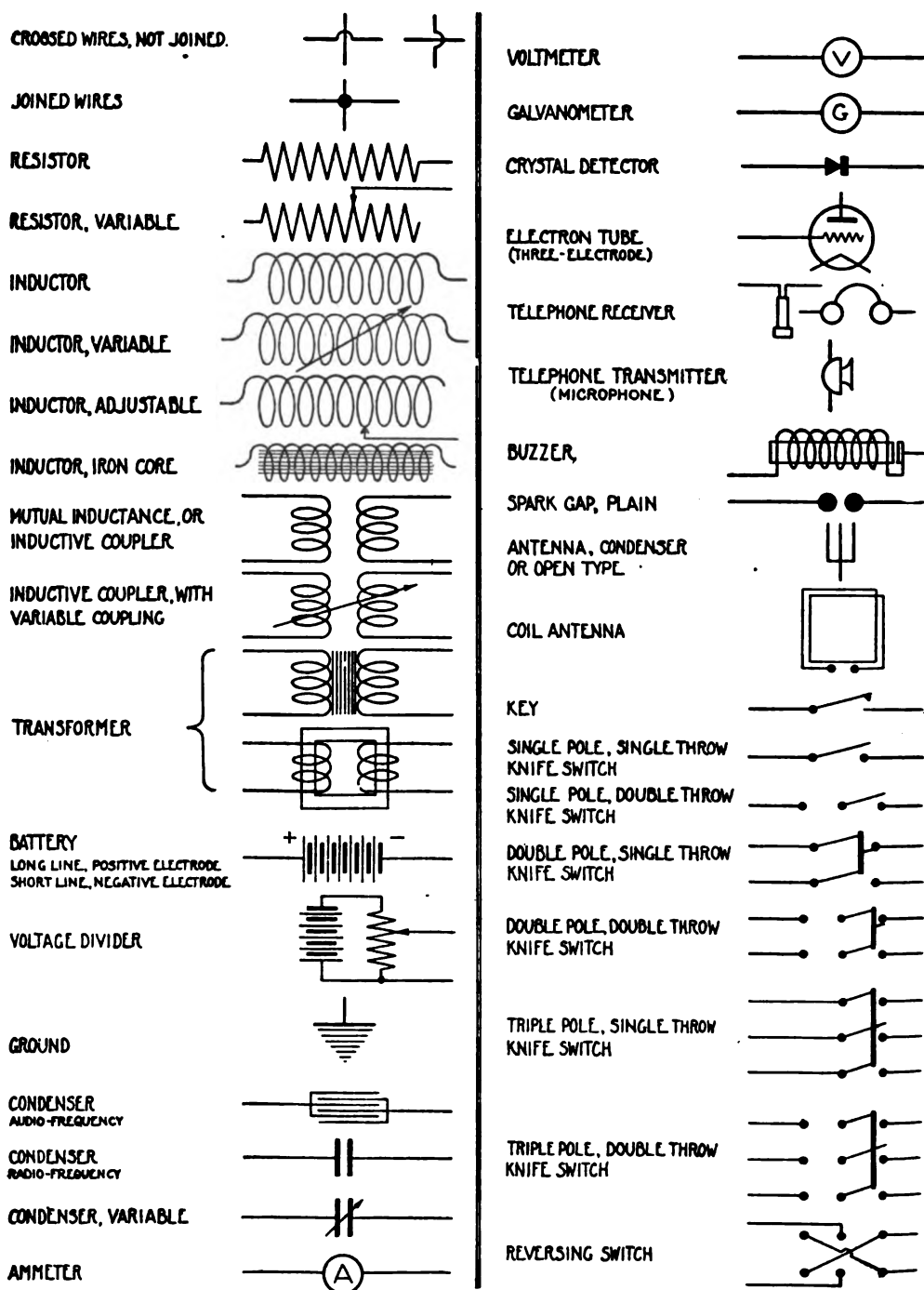


FIG. 4.—A few common wiring symbols used in schematic wiring diagrams.

**DEPARTMENT OF COMMERCE**

**CIRCULAR**  
**OF THE**  
**BUREAU OF STANDARDS**

**No. 142**

**TABLES OF THERMODYNAMIC PROPERTIES  
OF AMMONIA**

(1st Edition)

APRIL 16, 1923



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# TABLES OF THERMODYNAMIC PROPERTIES OF AMMONIA.

## ABSTRACT.

These tables embody the results of an elaborate series of measurements of the thermodynamic properties of ammonia. The fundamental units and constants used in the tables are defined. The empirical equations used in computing the tables, and also the references to the publications dealing with the experimental data, are given. The tables have been prepared in the forms convenient for use in refrigerating engineering. The same data are also presented graphically in the form of a Mollier chart.

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## I. INTRODUCTION.

These tables are the result of measurements made by the Bureau of Standards to determine fundamental physical data of refrigerating engineering. The bureau's researches in this field were undertaken in response to the wishes of the refrigerating industry as expressed through its national associations and were specifically authorized by act of Congress.<sup>1</sup> The experimental work on ammonia was done during the years 1915-1917 and 1920-1922, inclusive. In carrying out the experimental program the bureau has had the benefit of the advice of The American Society of Refrigerating Engineers, one of the organizations which originally requested that the work be done, and whose cooperation made it possible to carry the program through to a successful conclusion. The results obtained are in surprisingly good agreement with the average of the few values available when the work

<sup>1</sup> Act approved Aug. 24, 1912 (Public No. 302).

was begun and are, in general, in excellent agreement with recent work done elsewhere.

The bureau's work on ammonia has made it possible to prepare tables based upon a homogeneous body of accurately determined and thermodynamically consistent data relating to a material of a known and high degree of purity.

In order to make these tables available at an earlier date than would otherwise have been possible, this first edition is published in foot-pound-Fahrenheit units only. Tables in metric engineering units will be published subsequently.

## II. FUNDAMENTAL UNITS AND CONSTANTS.

*Temperature scale.*—The Fahrenheit scale used in these tables is derived from the standard centigrade scale by means of the relation

$$\text{Fahrenheit temperature} = 1.8 \times \text{centigrade temperature} + 32$$

Temperatures on the absolute Fahrenheit scale were obtained by adding  $459.58^\circ$  to the temperatures as defined above.

The standard centigrade scale adopted by the Bureau of Standards for the temperature interval  $-40$  to  $+450^\circ \text{C.}$  is the thermodynamic scale as realized by means of the resistance thermometer of pure platinum, standardized at the temperatures of melting ice ( $0^\circ \text{C.}$ ), condensing steam ( $100^\circ \text{C.}$ ), and condensing sulphur vapor ( $444.6^\circ \text{C.}$ ), all at standard atmospheric pressure. In the interval  $-50$  to  $+450^\circ \text{C.}$ , temperatures were calculated from the observed resistances of the thermometer by means of Callendar's well-known equation

$$t = \frac{R_t - R_0}{R_{100} - R_0} 100 + \delta \left( \frac{t}{100} - 1 \right) \frac{t}{100}$$

For temperatures below  $-50^\circ \text{C.}$ , corrections as found by Henning<sup>2</sup> were applied to temperatures calculated from the Callendar equation, the maximum correction so applied being  $+0.08^\circ \text{C.}$  at  $-78^\circ \text{C.}$  Temperatures on the absolute thermodynamic scale were obtained by adding  $273.1^\circ$  to the measured temperatures on the centigrade scale.

*Heat unit.*—The calorimetric measurements were all made in terms of the international joule, which was therefore the fundamental heat unit. It seems probable that the international joule is somewhat larger than the corresponding cgs unit, the relation as given in Bureau of Standards Circular No. 60, 2d edition (1920), being

$$1 \text{ International joule} = 1.00034 \text{ absolute joules.}$$

---

<sup>2</sup> Ann. d. Phys. (4), 40, p. 653; 1913.

In the thermodynamic equations relations occur between quantities of energy, some of which were measured in international joules while others, such as the product of pressure and volume, were measured directly in mechanical units; that is, absolute joules. Although the difference might be considered of negligible importance, it was taken into account where it could have had any appreciable effect on the results given. The basic heat unit used in calculating the tables was the absolute joule.

As secondary heat units the calorie and the British thermal unit (Btu.) have been used. The calorie is defined for the purposes of these tables as 4.183 absolute joules. It can not be stated with certainty at this time whether the calorie here used is larger or smaller than the mean calorie or the 20° calorie. Later investigations may serve to settle this point and to determine whether the calorie here used is equal to the 20° calorie or some other calorie.

The Btu. as here used is derivable from the calorie by relations which depend only upon the relative size of the centigrade and Fahrenheit degrees and the relation between the kilogram and the pound. Thus,

$$1 \text{ Btu.} \times 453.592 \times \frac{5}{9} = 252.00 \text{ calories} = 1,054.1 \text{ joules.}$$

This method of defining the Btu. retains the convenient relation

$$1 \text{ calorie per gram} = 1.8 \text{ Btu. per pound.}$$

*Unit of pressure.*—It is customary to express numerical values for pressures not in terms of force per unit area, but in terms of the equivalent weight per unit area. In order to make such values definite, it is necessary to specify the gravitational acceleration to which the weight is subjected. In conformity with the recommendation of the International Committee on Weights and Measures in 1901 the standard value taken for the acceleration due to gravity is 980.665 cm per sec. per sec. (32.174 feet per sec. per sec.). The unit of force is therefore equal to that force which is required to support a mass of 1 pound subjected to a gravitational acceleration of 32.174 feet per sec. per sec. The unit of pressure is equal to that pressure which exerts a unit force upon a unit of area, and, in these tables, is expressed in pounds per square inch.

*Mechanical equivalent of heat.*—The definitions given in the foregoing paragraphs, together with the relation between the foot and the meter and the pound and the kilogram, are sufficient to specify completely the numerical value to be used for the mechanical equivalent of heat.

$$1,054.1 \text{ joules} \times \frac{10^7 \times 0.3937}{980.665 \times 453.592 \times 12} = 777.46 \text{ ft.-lbs.}$$

or

$$1 \text{ Btu.} = 777.46 \text{ ft.-lbs.}$$

In using the tables, quantities of heat and quantities of work will be obtained in Btu., and the transformation into mechanical units is secured by multiplying by the factor 777.46. In the cases where the reverse transformation is desired the relation may be written

$$1 \text{ ft.-lb.} = 0.00128624 \text{ Btu.}$$

### III. EXPERIMENTAL DATA.

These tables are based upon measurements made in the Bureau of Standards' laboratories. Methods of purifying and testing ammonia were thoroughly investigated and material of a high degree of purity was produced and used throughout. Determinations of most of the measurable thermodynamic properties of ammonia were included in the experimental program, the range of temperature and pressure was at least as great as that likely to be encountered in engineering practice, and the measurements were extended beyond this range as far as could be done conveniently or safely with the apparatus used.

The tables are based primarily upon measurements of the following properties of ammonia:

1. Specific heat of saturated liquid.
2. Latent heat of vaporization.
3. Vapor pressure.
4. Specific volume of saturated liquid.
5. Specific volume of saturated vapor.
6. Specific heat of superheated vapor at constant pressure.
7. Specific volume of superheated vapor.

Measurements were also made of the latent heat of pressure variation, and the compressibility of the liquid and of the Joule-Thomson coefficient for the vapor. These auxiliary measurements were needed to provide data for the evaluation of certain correction terms occurring in the analysis of the principal experiments. The original researches were published in part in the Journal of the American Society of Refrigerating Engineers (now Refrigerating Engineering), in the Journal of the American Chemical Society, and in the Scientific Papers of the Bureau of Standards. The following Scientific Papers dealing with the subject have been published:

- S301. An aneroid calorimeter for specific and latent heats, B. S. Bulletin, **14**, p. 133; 1918. (Also in A. S. R. E. Jour., **4**, p. 103; 1917.)
- S313. Specific heat of liquid ammonia, B. S. Bulletin, **14**, p. 397; 1918. (Also in A. S. R. E. Jour., **4**, p. 134; 1917; and in J. Am. Chem. Soc., **40**, p. 1; 1918.)
- S314. Latent heat of pressure variation of liquid ammonia, B. S. Bulletin, **14**, p. 433; 1918. (Also in A. S. R. E. Jour., **4**, p. 167; 1917.)
- S315. Latent heat of vaporization of ammonia. B. S. Bulletin, **14**, p. 439; 1918. (Also in A. S. R. E. Jour., **4**, p. 172; 1917; and in J. Am. Chem. Soc., **40**, p. 14; 1918.)
- S369. Vapor pressure of ammonia. B. S. Sci. Papers, **16**, p. 1; 1920. (Also in A. S. R. E. Jour., **6**, p. 307; 1920; and in J. Am. Chem. Soc., **42**, p. 206; 1919.)

- S420. Specific volume of liquid ammonia. B. S. Sci. Papers, 17, p. 287; 1921. (Also in A. S. R. E. Jour., 7, p. 113; 1920.)
- S465. Composition, purification, and certain constants of ammonia. B. S. Sci. Papers, 18, p. 655; 1923. (Also in Ref. Eng., 9, p. 213; 1923.)
- S467. Specific volume of saturated ammonia vapor. B. S. Sci. Papers, 18, p. 707; 1923. (Also in Ref. Eng., 9, p. 239; 1923.)

Papers on the following subjects are in preparation and will be published in due course:

- A flow calorimeter for measuring the specific heat of gases.
- The specific heat of superheated ammonia vapor.
- The specific volume of superheated ammonia vapor.
- Derivation of empirical equations as a basis for ammonia tables.

Preliminary reports on two of these subjects have already been published, as follows:

Flow calorimeter, A. S. R. E. Jour., 7, p. 362; 1921; Phys. Rev., 20, p. 98; 1922.

Specific heat of superheated ammonia vapor. Ref. Eng., 9, p. 1; 1922.

The critical temperature of ammonia, where this value was required, was taken as  $133^{\circ}\text{C}$ . ( $271.4^{\circ}\text{F}$ ). This value is based on the measurements of Cardoso and Giltay.<sup>3</sup>

#### IV. NOTATION.

The adoption of a notation which shall be universally satisfactory has not yet been accomplished. In the original scientific papers dealing with properties of ammonia notations were used which served the requirements of those papers. For the purposes of these tables it appeared desirable to avoid the use of Greek letters, primes, or subscripts, and the following notation, which is believed to meet the requirements of the case, has been adopted. The formulas are given to remove any possible ambiguity in the interpretation of the various symbols.

Quantity.	Units.	Symbol.	Formula.
Pressure.....	lbs./in. <sup>2</sup> .....	p	
Gage pressure.....	lbs./in. <sup>2</sup> .....	g.p.	$g.p. = p - 14.7$
Temperature.....	$^{\circ}\text{F}$ .....	t	
Absolute temperature.....	$^{\circ}\text{F}$ .....	T	$T = t + 459.58$
Mechanical equivalent of heat.....	ft.-lbs./Btu.....	J	$J = 777.46$
Specific volume of liquid.....	ft. <sup>3</sup> /lb.....	v	
Specific volume of vapor.....	ft. <sup>3</sup> /lb.....	V	
Heat added (reversible process).....	Btu./lb.....	q	
Internal energy of liquid.....	Btu./lb.....	e	$de = dq - 0.18522 \text{ } pdv$
Internal energy of vapor.....	Btu./lb.....	E	$dE = dq - 0.18522 \text{ } pdV$
Heat content of liquid (also called total heat of liquid).....	Btu./lb.....	h	$dh = de + 0.18522 \text{ } d(pv)$
Heat content of vapor.....	Btu./lb.....	H	$dH = dE + 0.18522 \text{ } d(pV)$
Entropy of liquid.....	Btu./lb. $^{\circ}\text{F}$ .....	s	$ds = dq/T$
Entropy of vapor.....	Btu./lb. $^{\circ}\text{F}$ .....	S	$dS = dq/T$
Quality; mass of vapor per unit mass of saturated mixture.....		x	
Latent heat of vaporization.....	Btu./lb.....	L	$L = (\partial q / \partial x)_t$
Latent heat of pressure variation.....	Btu./lb.....	l	$l = (\partial q / \partial p)_t$
Specific heat of saturated liquid.....	lb./in. <sup>3</sup> .....		
	Btu./lb. $^{\circ}\text{F}$ .....	c	$c = (\partial q / \partial t)_{\text{sat.}}$
Compressibility of liquid.....	$\frac{1}{\text{lb./in.}^3}$		$\text{comp} = -\frac{1}{v} \left( \frac{\partial v}{\partial p} \right)_t$

<sup>3</sup> Arch. Sci. Phys. Nat. Genève, 34, p. 20; 1912.

## V. EMPIRICAL EQUATIONS.

When the results of the earlier investigations were published, empirical equations were chosen which represented closely the results of the measurements. The forms of these equations were chosen so that they would be consistent with known facts as to the behavior of substances at the critical temperature, so that extrapolation beyond the experimental range could be made with some confidence.

In combining all of the results into a thermodynamically consistent system, some of the original equations could not be retained, while others required slight modification. A set of empirical equations has been formulated, which, within the range of the measurements, are consistent with the laws of classical thermodynamics, and, in addition, express the experimental data within the estimated limit of accuracy of the latter.

The specific volume, heat content, and entropy of the superheated vapor were calculated by means of three empirical equations of the following forms:

$$V = \frac{AT}{p} - \left( \frac{B}{T^3} + \frac{C + Dp}{T^{11}} + \frac{Ep^5}{T^{10}} \right) - F + Tf_1(p) \quad (1)$$

$$H = A \log_{10} T - p \left( \frac{B}{T^3} + \frac{C + Dp}{T^{11}} + \frac{Ep^5}{T^{10}} \right) - Fp + GT + IT^2 + K \quad (2)$$

$$S = A \log_{10} T - \frac{p}{T} \left( \frac{B}{T^3} + \frac{C + Dp}{T^{11}} + \frac{Ep^5}{T^{10}} \right) - F \log_{10} p + GT - \frac{I}{T} + f_2(p) + K \quad (3)$$

The corresponding properties of the saturated vapor were calculated by solving the above equations simultaneously with the vapor-pressure equation of the following form:

$$\log_{10} p = A - \frac{B}{T} - C \log_{10} T - DT + ET^2 \quad (4)$$

The properties of the saturated liquid were calculated from equations of the following forms:

$$L = \frac{144}{J} T(V - v) \frac{dp}{dT} \quad (\text{saturation}) \quad (5)$$

$$v = \frac{A + B\sqrt{t_k - t} - C(t_k - t)}{1 + D\sqrt{t_k - t} + E(t_k - t)} \quad (6)$$

$$h = H - L \quad (7)$$

$$s = S - \frac{L}{T} \quad (8)$$

in which  $H$ , equation (7), and  $S$ , equation (8), apply to properties of the saturated vapor. The compressibility of the liquid was calculated by means of an empirical equation of the form

$$-\frac{1}{v} \left( \frac{\partial v}{\partial p} \right)_t = A + \frac{B}{(t_k - t)^2} \quad (9)$$

Other properties of the liquid under moderate pressures greater than saturation pressure were calculated from the following equations:

$$\left( \frac{\partial v}{\partial t} \right)_p = \left( \frac{dv}{dt} \right)_{\text{sat.}} + \left[ \left( \frac{\partial v}{\partial p} \right)_t \frac{dp}{dt} \right]_{\text{sat.}} - \int_{p(\text{sat.})}^p \frac{\partial}{\partial t} \left( \frac{\partial v}{\partial p} \right)_t dp \quad (10)$$

$$l = -\frac{144}{J} T \left( \frac{\partial v}{\partial t} \right)_p \quad (11)$$

$$\left( \frac{\partial h}{\partial p} \right)_t = -\frac{144}{J} \left[ T \left( \frac{\partial v}{\partial t} \right)_p - v \right] \quad (12)$$

The constants used in the above equations are tabulated below:

Constant.	Equation number.					
	(1)	(2)	(3)	(4)	(6)	(9)
A	0.6301952	$7.60959 \times 10$	0.619546	$2.55743247 \times 10$	$6.86064 \times 10^{-3}$	$1.164 \times 10^{-6}$
B	$3.18228 \times 10^{-7}$	$2.3577 \times 10^{-7}$	$1.7683 \times 10^{-7}$	$3.2951254 \times 10^{-3}$	$9.7073 \times 10^{-3}$	0.3567
C	$3.80226 \times 10^{-37}$	$8.451 \times 10^{-37}$	$7.747 \times 10^{-37}$	6.4012471	$7.3738 \times 10^{-5}$	.....
D	$2.29909 \times 10^{-36}$	$2.555 \times 10^{-36}$	$2.3421 \times 10^{-36}$	$4.148279 \times 10^{-4}$	0.31663	.....
E	$1.1778 \times 10^{-36}$	$7.272 \times 10^{-37}$	$6.908 \times 10^{-37}$	$1.4759945 \times 10^{-6}$	$8.8544 \times 10^{-3}$	.....
F	0.041648	0.007714	0.2687723	.....	.....	.....
G	.....	0.269065	$3.16094 \times 10^{-4}$	.....	.....	.....
I	.....	$1.58047 \times 10^{-4}$	$3.3048 \times 10$	.....	.....	.....
K	.....	$2.62303 \times 10^{-4}$	0.028463	.....	.....	.....

$$f_1(p) = (5300 - 32p + 0.10132p^2 - 0.0000992p^3) 10^{-6},$$

$$f_2(p) = -p(982 - 2.964p + 0.006255p^2 - 0.00000459p^3) 10^{-6},$$

$$t_k = 271.4^\circ.$$

The equations are complicated, but no simpler forms have been found which would satisfy all the requirements. The forms of some of the equations are such that extrapolation much beyond the range of the measurements is not warranted. A detailed account of the derivation of these equations and their agreement with the experimental data is reserved for another publication.

## VI. DESCRIPTION OF THE TABLES.

Three principal sets of tables are given: (a) Properties of saturated fluid, (b) properties of the liquid, and (c) properties of the superheated vapor.

The tabulation of the properties of saturated fluid is relatively simple, since only one coordinate is required to fix the values for this state. As a

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matter of convenience three separate tables (Tables 1, 2, and 3) of the properties of saturated fluid have been prepared, in which the arguments are temperature, absolute pressure, and gage pressure, respectively. Gage pressure has been included because it is unfortunately true that it will continue to be used in spite of its evident disadvantages. In each of the tables the intervals have been so chosen that linear interpolation is easy and accurate.

In addition to the arguments, pressure and temperature, these tables contain values of the specific volume, density, heat content, and entropy of the saturated vapor, of the heat content and entropy of the saturated liquid, and of the latent heat and entropy of vaporization. On account of lack of space, values for the entropy of vaporization were omitted from Table 1.

It may be noted that certain quantities, such as internal energy and internal latent heat, which appear in some other ammonia tables have been omitted because they are seldom required and, in case of necessity, are readily calculated from the tabulated data.

Both the heat content and entropy of saturated liquid have been arbitrarily assigned the value of zero for the temperature of  $-40^{\circ}$  F. or C. This selection was made partly because  $-40^{\circ}$  represents the same temperature on both the Fahrenheit and centigrade scales and partly because negative values of heat content or entropy would not then be encountered in the usual working range of the tables.

A separate table (Table 4) of the properties of liquid ammonia, with temperature at intervals of  $5^{\circ}$  as the argument, has been included. The range of this table extends from the triple (freezing) point to the critical temperature, and the table includes data on all of the thermodynamic quantities which were measured at this bureau. The figures given in parentheses represent extrapolations beyond the range of the measurements, and their correctness is therefore uncertain. The data in Table 4 are not often required in engineering practice, but are useful for reference.

Since two coordinates or arguments are necessary to specify the state of a superheated vapor, a table of the properties of the vapor will be much more voluminous than the tables for saturated fluid. Temperature and pressure are conveniently used as arguments, but in order to limit the table to a reasonable size, the chosen intervals must be considerably wider than those used in the saturation tables. The arrangement of the superheat table (Table 5) is similar to that used by Goodenough.<sup>4</sup> For a series of suitably chosen pressures, values of specific volume, heat content, and entropy are tabulated, corresponding to a number of temperatures at

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<sup>4</sup> Properties of steam and ammonia, John Wiley & Sons, New York; 1915.

suitably chosen intervals. The intervals of both temperature and pressure are so chosen that no accuracy is lost by linear interpolation. For the convenience of the user certain entries in this table appear in duplicate, which facilitates interpolation.

In computing the figures in the tables from the empirical equations (Section V) all calculations were carried two digits beyond the number to be finally retained in the tables. A first check on the correctness of these numbers was obtained by the method of differences. The rounded off values in the tables have also been checked throughout by the method of differences. Numerous tests of the consistency of the tables have been made by substituting values derived from the tables, in general thermodynamic equations such as

$$\left(\frac{\partial H}{\partial t}\right)_p = T \left(\frac{\partial S}{\partial t}\right)_p; \left(\frac{\partial S}{\partial p}\right)_t = -\left(\frac{\partial V}{\partial t}\right)_p; \left(\frac{\partial H}{\partial S}\right)_p = T$$

## VII. DESCRIPTION OF THE MOLLIER CHART.

Instead of tabulating numerical values of the properties of ammonia, it is possible to present the same data graphically by means of a chart. For this purpose any two independent coordinates, such as pressure and volume, may be chosen and lines representing constant values of other quantities drawn in their proper places on the chart. Since such a chart would contain five sets of lines representing constant values of pressure, temperature, volume, heat content, and entropy, it is obvious that it would be possible to choose any two of these quantities as "coordinates." The practical usefulness of such a chart depends very much, however, upon what coordinates are chosen. Because accuracy in reading numerical values of heat content is of prime importance, heat content should be chosen as one coordinate.

Charts of this type, which are known as Mollier charts, were introduced by Mollier,<sup>5</sup> who illustrated several forms. Examination of the various forms which these charts assume<sup>6</sup> with some of the other variables as the second coordinate has led to the choice of the logarithm of pressure as the second coordinate, a form already adopted by Callendar.<sup>7</sup> For the chart accompanying these tables heat content was chosen as abscissa, as this makes it possible to use an open scale of heat content and at the same time keep the height of the chart within convenient limits.

Each point at the left of the chart in the region of compressed liquid represents a definite state of the liquid. Each point in the region of superheated vapor represents a definite state of the vapor. Since the state of

<sup>5</sup> *Zs. d. Ver. Deutscher. Ing.*, 48, (1), p. 271; 1904.

<sup>6</sup> *A. S. R. E. Jour.*, 7, p. 419; 1921.

<sup>7</sup> The Callendar steam tables; Longmans, Green & Co.; 1915.

saturated vapor or liquid is determined by a single coordinate, the properties of saturated vapor are represented on the chart by a single line, while those of the liquid are represented by another line, the region between these lines being the region of mixtures. In this region lines of constant quality have been drawn. Since mixtures containing between 20 and 80 per cent vapor are not of much interest in engineering calculations, the central part of the chart has been condensed. It appeared preferable to condense this part of the chart rather than omit it entirely.

The chart as originally drawn is 390 by 1,014 mm (approximately 16 by 40 inches). The ends of each coordinate line were located by means of a beam compass and an accurate scale. Each curve was located by means of a considerable number of suitably chosen points, obtained directly or by interpolation from the tables. The bureau is indebted to the U. S. Coast and Geodetic Survey for advice on the technique of preparing such charts and for loan of equipment.

After the chart was drawn readings were taken systematically on all parts, tabulated, and compared with the tables. In the superheat region about 1,500 values corresponding to 500 distinct points were read. On the lines of saturated liquid and vapor readings were taken at intervals of  $10^{\circ}$ . In the region of mixtures about 500 readings were made. A few readings were also taken in the region of compressed liquid. The maximum departures of the chart readings from the tabular values were found to be as follows:

The maximum departures of values of entropy as read on the chart from those obtained from the tables were 0.0006 in the region of mixtures and 0.0011 in the superheat region, corresponding to 0.3 and 0.7 Btu., respectively. The maximum departure in temperature was  $0.7^{\circ}$  in the superheat region and only  $0.2^{\circ}$  elsewhere. The maximum departure in quality was 0.0009, except in the condensed part of the chart. The departures of values of volume above 500 Btu. did not exceed 0.7 per cent. In the region of mixtures, just above saturated liquid, volumes become very small and the percentage errors in volume, due to very small displacements in the curves or errors in reading, become very large, increasing almost without limit as the liquid line is approached, so that any definite statement as to percentage errors would be misleading. The error in locating the constant volume lines in this region was less than 0.4 mm on the original chart.

A sufficient number of lines have been drawn on the chart so that accurate interpolation is possible without recourse to measurements of distance. Since a photographic process was employed in reproducing the original chart, any distortion incident to this process would not impair

the accuracy of the copy, the only loss of accuracy being that accompanying the reduction in size. The accuracy of the printed chart is likewise not impaired by the dimensional changes to which paper is subject.

### VIII. USE OF TABLES AND CHART.

The use of the tables and chart is based largely on three properties of the thermodynamic function called the heat content of a fluid. The three properties referred to are the following:

1. In any process which occurs at constant pressure the increase in heat content is equal to the heat added.

2. In adiabatic compression—that is, at constant entropy—the thermal equivalent of the work done by the compressor is equal to the change in heat content of the fluid between inlet and outlet.

3. In a throttling process, such as occurs at the expansion valve, the increase in heat content is equal to the heat added. Therefore, when no heat is added, the heat content is constant.

By the application of these three propositions the various quantities of heat and work involved in any ideal compression refrigerating cycle can be calculated from either the tables or the chart. It will, perhaps, be useful to show this by a numerical example worked out from both the tables and the chart. Suppose saturated vapor at the temperature of  $5^{\circ}$  is delivered to the compressor, compressed to a pressure corresponding to saturation at  $86^{\circ}$ , cooled and condensed to the liquid state at this pressure, expanded through a throttle valve to the pressure at the compressor inlet, and finally after complete evaporation is returned to the compressor. Suppose, further, that the cycle is ideal—that is, the compressor has no clearance—no pressure drop occurs except at the expansion valve and no heat exchange except in the condenser and evaporator. Given these conditions, it is required to find:

1. Pressure at compressor inlet.
2. Specific volume of vapor at compressor inlet.
3. Pressure at compressor outlet; that is, pressure in condenser.
4. Temperature of superheated vapor at compressor outlet.
5. Specific volume of superheated vapor at compressor outlet.
6. Work done by compressor per pound of ammonia circulated.
7. Heat removed by cooling water per pound of ammonia.
8. Heat absorbed by ammonia in evaporator; that is, refrigerating effect per pound of ammonia.
9. Quality of mixture after passing through the expansion valve.
10. Number of pounds of ammonia circulated per minute for a standard commercial ton of refrigeration.
11. Volume of ammonia delivered to compressor per minute for a standard commercial ton of refrigeration.

12. Horsepower required per standard commercial ton of refrigeration.

13. Coefficient of performance.

The pressure (item 1) and specific volume (item 2) at compressor inlet are found in Table 1, being, respectively, the pressure (34.27 lbs./in.<sup>2</sup>) and specific volume (8.150 ft.<sup>3</sup>/lb.) of saturated vapor at 5°. Similarly, the pressure at compressor outlet (item 3) is the pressure (169.2 lbs./in.<sup>2</sup>) of saturated vapor at 86°. On the chart saturation pressures are more accurately read on the liquid line, on which temperatures at intervals of 2° are indicated.

The temperature (item 4) and specific volume (item 5) of the superheated vapor at the compressor outlet are found on the chart by following the (interpolated) line of constant entropy from saturated vapor at 34.3 lbs./in.<sup>2</sup> to its intersection with the line of 169 lbs./in.<sup>2</sup>. At this point the temperature (210°) and specific volume (2.36 ft.<sup>3</sup>/lb.) are found. To obtain similar results from the tables the entropy (1.3253) of the saturated vapor at 5° is read from Table 1, and the temperature (209.8°) and specific volume (2.358 ft.<sup>3</sup>/lb.) corresponding to this value of entropy and the pressure of 169.2 lbs./in.<sup>2</sup> are obtained by interpolation.

The work done by the compressor per pound of ammonia circulated (item 6) is found in thermal units from either the chart or the tables as the increase in heat content between compressor inlet (613.3 Btu./lb.) and outlet (712.9 Btu./lb.) or 99.6 Btu./lb.

The heat removed by the cooling water per pound of ammonia circulated (item 7) is found in the same manner as the decrease in heat content between superheated vapor at compressor outlet (712.9 Btu./lb.) and saturated liquid at 86° (138.9 Btu./lb.) or 574 Btu./lb.

The refrigerating effect per pound of ammonia (item 8) is found as the difference between the quantity of heat removed by the cooling water (574 Btu./lb.) and the work done by the compressor (99.6 Btu./lb.) or 474.4 Btu./lb. This quantity may also be found as the increase in heat content between saturated liquid at 86° (138.9 Btu./lb.) and saturated vapor at 5° (613.3 Btu./lb.).

The quality of the mixture (item 9) can be read directly from the chart by following a line of constant heat content from saturated liquid at 86° (138.9 Btu./lb.) to its intersection with the line of constant pressure at 34.3 lbs./in.<sup>2</sup>. At this point the quality is read as 0.161, which signifies that 16.1 per cent of the liquid was evaporated in passing through the expansion valve. This value of quality can not be read directly from the tables but can be calculated from the tabulated data, using the equation:

$$\text{Quality} = \frac{h_{86^\circ} - h_{5^\circ}}{H_{5^\circ} - h_{5^\circ}} = \frac{138.9 - 48.3}{613.3 - 48.3} = 0.1603$$

The American Society of Refrigerating Engineers has defined the standard commercial ton of refrigeration as a rate which is equivalent to the transfer of 200 Btu. per minute.<sup>8</sup> The number of pounds of ammonia which must be circulated per minute for a standard commercial ton of refrigeration (item 10) is therefore equal to 200 divided by the refrigerating effect per pound of ammonia (474.4 Btu.), the result being 0.4216 lbs./min.

The volume of ammonia which must be delivered to the compressor per minute for a standard commercial ton of refrigeration (item 11) is equal to the number of pounds of ammonia circulated per minute (0.4216) multiplied by the specific volume of the ammonia at the compressor inlet (8.150 ft.<sup>3</sup>/lb.) the result being 3.436 ft.<sup>3</sup>/min.

The horsepower required per standard commercial ton of refrigeration (item 12) is found by multiplying the thermal equivalent of the work of compression (99.6 Btu./lb.) by the number of pounds of ammonia circulated per minute (0.4216), and reducing to horsepower by the use of the appropriate factors, as follows:

$$\text{H. P./ton} = \frac{99.6 \times 0.4216 \times 777.46}{33000} = 0.989$$

The coefficient of performance (item 13), ratio of the heat absorbed in the evaporator (474.4 Btu./lb.) to the thermal equivalent of the work of compression (99.6 Btu./lb.), is equal to 4.764.

The following table gives the numerical values of the various items as obtained from the tables and chart. For the sake of comparison figures derived from the tables of Keyes and Brownlee,<sup>9</sup> and of Goodenough and Mosher,<sup>10</sup> are also given. The figures read from the chart represent the average readings of five persons. In a separate column the maximum deviation of individual chart readings from the mean is given.

Item.	Quantity.	Bureau of Standards tables.	Good-enough and Mosher tables.	Keyes and Brownlee tables.	Bureau of Standards chart.	Maximum deviation of individual chart readings.
1	Inlet pressure.....	34.27	33.79	34.47	34.4	0.1
2	Inlet volume.....	8.150	8.20	8.20	8.2	0.0
3	Outlet pressure.....	169.2	170.2	170.5	169.0	0.0
4	Outlet temperature.....	209.8	213.8	255.6	210	1.0
5	Outlet volume.....	2.358	2.34	2.505	2.36	0.01
6	Work of compression.....	99.6	100.8	104.8	99.4	0.5
7	Heat removed by condenser.....	574.0	580.1	588.1	574.0	0.6
8	Heat absorbed in evaporator.....	474.4	469.3	483.3	474.6	0.2
9	Quality after expansion.....	0.1603	0.1566	0.1617	0.161	0.001
10	Lbs. NH <sub>3</sub> per min. per ton refrigeration.....	0.4216	0.4262	0.4138	0.4214	.....
11	Ft. <sup>3</sup> NH <sub>3</sub> per min. per ton refrigeration.....	3.436	3.494	3.393	3.456	.....
12	H.P. per ton refrigeration.....	0.989	1.012	1.022	0.987	.....
13	Coefficient of performance.....	4.764	4.656	4.612	4.775	.....

<sup>8</sup> A. S. R. E. Jour., 7, p. 322; 1921.  
<sup>9</sup> Thermodynamic properties of ammonia, John Wiley & Sons, New York; 1916.  
<sup>10</sup> Univ. of Ill. Bulletin, No. 66; 1913.

## IX. GRAPHS OF CERTAIN PROPERTIES OF AMMONIA.

Although numerical values of all of the properties of ammonia which are of interest to the engineer may be read or derived from the tables or chart, a few small figures are reproduced here to illustrate graphically how some of the important properties vary with the temperature. These graphs may enable those not familiar with these properties to visualize more clearly their general behavior with respect to this variable.

Figure 1 shows the saturation vapor pressure and illustrates the relatively slow rate of increase of this pressure at low temperatures and the higher rate of increase at higher temperatures.

Figure 2 shows the variation with temperature of the specific volume of the saturated vapor and of the superheated vapor for several pressures. The figure illustrates the rapid increase in the volume of saturated vapor with decreasing temperature. The region below the saturated vapor line represents volumes of mixtures of liquid and vapor. The dotted adiabatic compression curve, or line of constant entropy, illustrates the variation of volume during an ideal process of adiabatic compression. This curve starts at the comparatively low pressure of 6 lbs./in.<sup>2</sup> absolute, so that volumes in the region above the curve are rarely encountered in engineering practice. The useful region is therefore that between the adiabatic compression curve and the curve for saturated vapor.

Figure 3 shows the variation with temperature of the latent heat of vaporization and of the heat content of liquid and vapor. These curves have been extended to the critical temperature in order to show their characteristics more clearly, namely, that the latent heat becomes zero at the critical temperature and that the heat content of liquid and vapor become identical. The latent heat at any temperature is equal to the difference between the heat content of vapor and liquid, respectively, at that temperature.

Figure 4 shows the variations with temperature of the specific heat,  $C_p$ , of the vapor for several constant pressures and shows, on the curve of saturation values, the limiting values of  $C_p$  at saturation temperatures and corresponding saturation pressures. These curves are of value chiefly in showing that  $C_p$  can not be considered as even approximately constant. One great advantage of using the tables of the Mollier chart is that it is not necessary to use values of  $C_p$  at all, since the necessary data can be obtained from the appropriate values of heat content.

WASHINGTON, February 26, 1923.

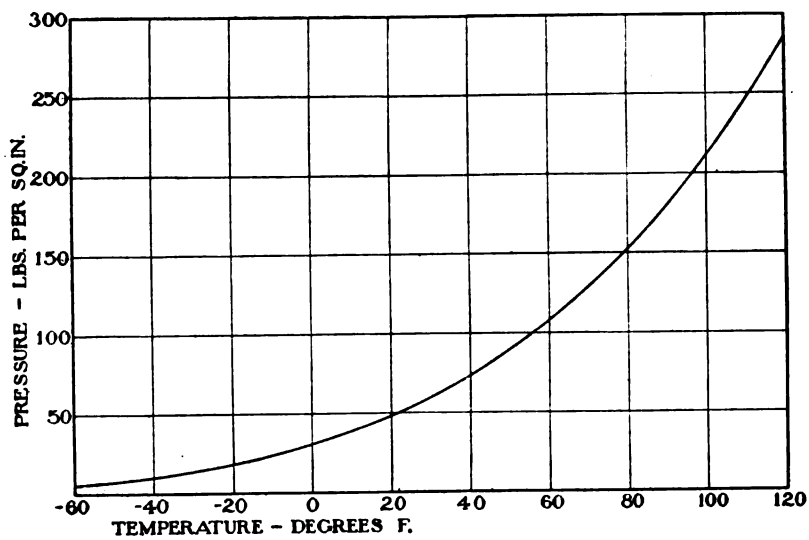


FIG. 1.—Vapor pressure of ammonia.

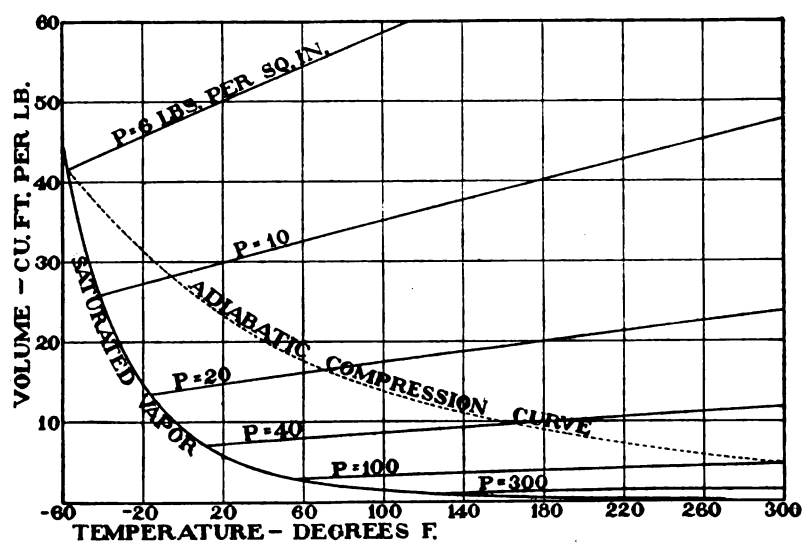


FIG. 2.—Specific volume of ammonia vapor.

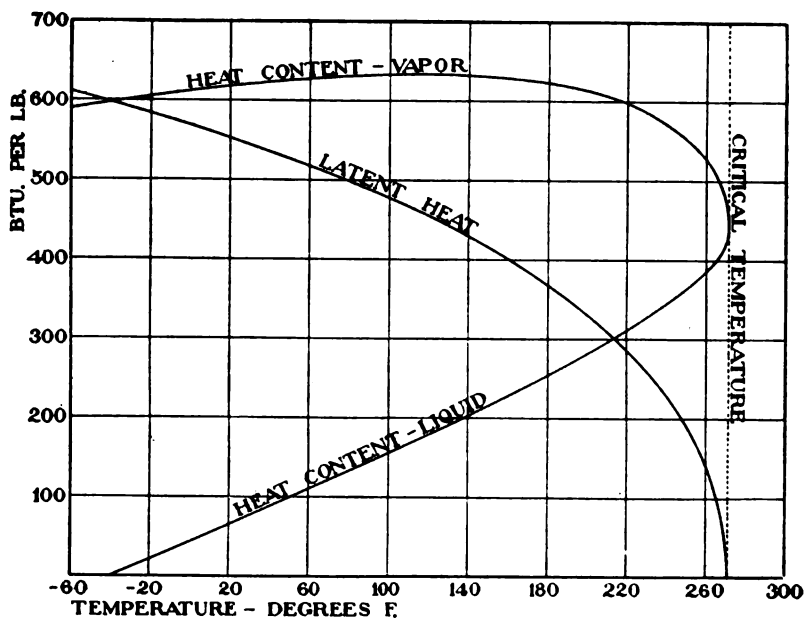


FIG. 3.—Latent heat of vaporization and heat content of saturated ammonia vapor and liquid.

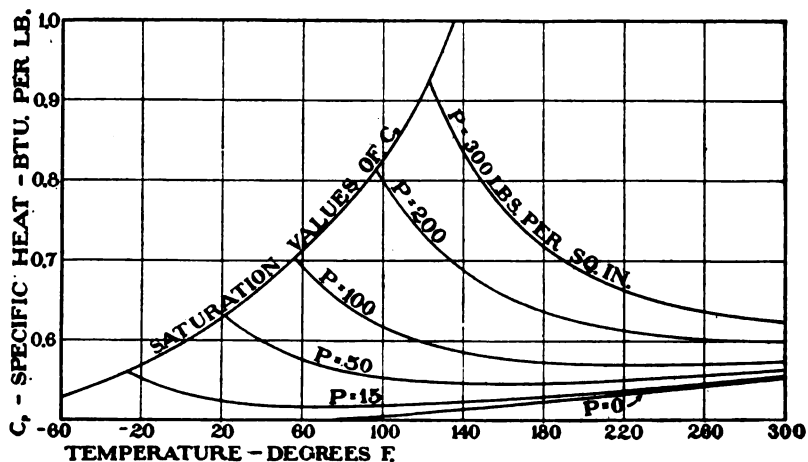


FIG. 4.—Specific heat of ammonia vapor at constant pressure.

**X. TABLES 1 TO 5.**

**TABLE 1.—Saturated Ammonia: Temperature Table.**

Temp. °F. <i>t</i>	Pressure.		Volume vapor. ft <sup>3</sup> /lb.	Density vapor. lbs./ft. <sup>3</sup> <i>1/V</i>	Heat content.		Latent heat. Btu./lb. <i>L</i>	Entropy.		Temp. °F. <i>t</i>
	Absolute. lbs./in. <sup>2</sup> <i>p</i>	Gage. lbs./in. <sup>2</sup> <i>g. p.</i>			Liquid. Btu./lb. <i>h</i>	Vapor. Btu./lb. <i>H</i>		Liquid. Btu./lb. °F. <i>s</i>	Vapor. Btu./lb. °F. <i>S</i>	
-60	5.55	*18.6	44.73	0.02235	-21.2	589.6	610.8	-0.0517	1.4769	-60
-59	5.74	*18.2	43.37	.02306	-20.1	590.0	610.1	-.0490	.4741	-59
-58	5.93	*17.8	42.05	.02378	-19.1	590.4	609.5	-.0464	.4713	-58
-57	6.13	*17.4	40.79	.02452	-18.0	590.8	608.8	-.0438	.4686	-57
-56	6.33	*17.0	39.56	.02528	-17.0	591.2	608.2	-.0412	.4658	-56
-55	6.54	*16.6	38.38	0.02605	-15.9	591.6	607.5	-0.0386	1.4631	-55
-54	6.75	*16.2	37.24	.02685	-14.8	592.1	606.9	.0360	.4604	-54
-53	6.97	*15.7	36.15	.02766	-13.8	592.4	606.2	-.0334	.4577	-53
-52	7.20	*15.3	35.09	.02850	-12.7	592.9	605.6	-.0307	.4551	-52
-51	7.43	*14.8	34.06	.02936	-11.7	593.2	604.9	-.0281	.4524	-51
-50	7.67	*14.3	33.08	0.03023	-10.6	593.7	604.3	-0.0256	1.4497	-50
-49	7.91	*13.8	32.12	.03113	-9.6	594.0	603.6	-.0230	.4471	-49
-48	8.16	*13.3	31.20	.03205	-8.5	594.4	602.9	-.0204	.4445	-48
-47	8.42	*12.8	30.31	.03299	-7.4	594.9	602.3	-.0179	.4419	-47
-46	8.68	*12.2	29.45	.03395	-6.4	595.2	601.6	-.0153	.4393	-46
-45	8.95	*11.7	28.62	0.03494	-5.3	595.6	600.9	-0.0127	1.4368	-45
-44	9.23	*11.1	27.82	.03595	-4.3	596.0	600.3	-.0102	.4342	-44
-43	9.51	*10.6	27.04	.03698	-3.2	596.4	599.6	-.0076	.4317	-43
-42	9.81	*10.0	26.29	.03804	-2.1	596.8	598.9	-.0051	.4292	-42
-41	10.10	*9.3	25.56	.03912	-1.1	597.2	598.3	-.0025	.4267	-41
-40	10.41	*8.7	24.86	0.04022	0.0	597.6	597.6	0.0000	1.4242	-40
-39	10.72	*8.1	24.18	.04135	1.1	598.0	596.9	.0025	.4217	-39
-38	11.04	*7.4	23.53	.04251	2.1	598.3	596.2	.0051	.4193	-38
-37	11.37	*6.8	22.89	.04369	3.2	598.7	595.5	.0076	.4169	-37
-36	11.71	*6.1	22.27	.04489	4.3	599.1	594.8	.0101	.4144	-36
-35	12.05	*5.4	21.68	0.04613	5.3	599.5	594.2	0.0126	1.4120	-35
-34	12.41	*4.7	21.10	.04739	6.4	599.9	593.5	.0151	.4096	-34
-33	12.77	*3.9	20.54	.04868	7.4	600.2	592.8	.0176	.4072	-33
-32	13.14	*3.2	20.00	.04999	8.5	600.6	592.1	.0201	.4048	-32
-31	13.52	*2.4	19.48	.05134	9.6	601.0	591.4	.0226	.4025	-31
-30	13.90	*1.6	18.97	0.05271	10.7	601.4	590.7	0.0250	1.4001	-30
-29	14.30	*0.8	18.48	.05411	11.7	601.7	590.0	.0275	.3978	-29
-28	14.71	0.0	18.00	.05555	12.8	602.1	589.3	.0300	.3955	-28
-27	15.12	0.4	17.54	.05701	13.9	602.5	588.6	.0325	.3932	-27
-26	15.55	0.8	17.09	.05850	14.9	602.8	587.9	.0350	.3909	-26
-25	15.98	1.3	16.66	0.06003	16.0	603.2	587.2	0.0374	1.3886	-25
-24	16.42	1.7	16.24	.06158	17.1	603.6	586.5	.0399	.3863	-24
-23	16.88	2.2	15.83	.06317	18.1	603.9	585.8	.0423	.3840	-23
-22	17.34	2.6	15.43	.06479	19.2	604.3	585.1	.0448	.3818	-22
-21	17.81	3.1	15.05	.06644	20.3	604.6	584.3	.0472	.3796	-21
-20	18.30	3.6	14.68	0.06813	21.4	605.0	583.6	0.0497	1.3774	-20
-19	18.79	4.1	14.32	.06985	22.4	605.3	582.9	.0521	.3752	-19
-18	19.30	4.6	13.97	.07161	23.5	605.7	582.2	.0545	.3729	-18
-17	19.81	5.1	13.62	.07340	24.6	606.1	581.5	.0570	.3708	-17
-16	20.34	5.6	13.29	.07522	25.6	606.4	580.8	.0594	.3686	-16
-15	20.88	6.2	12.97	0.07709	26.7	606.7	580.0	0.0618	1.3664	-15
-14	21.43	6.7	12.66	.07898	27.8	607.1	579.3	.0642	.3643	-14
-13	21.99	7.3	12.36	.08092	28.9	607.5	578.6	.0666	.3621	-13
-12	22.56	7.9	12.06	.08289	30.0	607.8	577.8	.0690	.3600	-12
-11	23.15	8.5	11.78	.08490	31.0	608.1	577.1	.0714	.3579	-11
-10	23.74	9.0	11.50	0.08695	32.1	608.5	576.4	0.0738	1.3558	-10

\* Inches of mercury below one standard atmosphere (29.92 in.).

TABLE 1.—Saturated Ammonia: Temperature Table—Continued.

Temp. °F.	Pressure.		Volume vapor. ft. <sup>3</sup> /lb.	Density vapor. lbs./ft. <sup>3</sup>	Heat content.		Latent heat. Btu./lb.	Entropy.		Temp. °F.
	Absolute. lbs./in. <sup>2</sup>	Gage. lbs./in. <sup>2</sup>			Liquid. Btu./lb.	Vapor. Btu./lb.		Liquid. Btu./lb. °F.	Vapor. Btu./lb. °F.	
<i>t</i>	<i>p</i>	<i>g. p.</i>	<i>V</i>	<i>1/V</i>	<i>h</i>	<i>H</i>	<i>L</i>	<i>s</i>	<i>S</i>	<i>t</i>
-10	23.74	9.0	11.50	0.08695	32.1	608.5	576.4	0.0738	1.3558	-10
-9	24.35	9.7	11.23	.08904	33.2	608.8	575.6	.0762	.3537	-9
-8	24.97	10.3	10.97	.09117	34.3	609.2	574.9	.0786	.3516	-8
-7	25.61	10.9	10.71	.09334	35.4	609.5	574.1	.0809	.3495	-7
-6	26.26	11.6	10.47	.09555	36.4	609.8	573.4	.0833	.3474	-6
-5	26.92	12.2	10.23	0.09780	37.5	610.1	572.6	0.0857	1.3454	-5
-4	27.59	12.9	9.991	.1001	38.6	610.5	571.9	.0880	.3433	-4
-3	28.28	13.6	9.763	.1024	39.7	610.8	571.1	.0904	.3413	-3
-2	28.98	14.3	9.541	.1048	40.7	611.1	570.4	.0928	.3393	-2
-1	29.69	15.0	9.326	.1072	41.8	611.4	569.6	.0951	.3372	-1
0	30.42	15.7	9.116	0.1097	42.9	611.8	568.9	0.0975	1.3352	0
1	31.16	16.5	8.912	.1122	44.0	612.1	568.1	.0998	.3332	1
2	31.92	17.2	8.714	.1148	45.1	612.4	567.3	.1022	.3312	2
3	32.69	18.0	8.521	.1174	46.2	612.7	566.5	.1045	.3292	3
4	33.47	18.8	8.333	.1200	47.2	613.0	565.8	.1069	.3273	4
5	34.27	19.6	8.150	0.1227	48.3	613.3	565.0	0.1092	1.3253	5
6	35.09	20.4	7.971	.1254	49.4	613.6	564.2	.1115	.3234	6
7	35.92	21.2	7.798	.1282	50.5	613.9	563.4	.1138	.3214	7
8	36.77	22.1	7.629	.1311	51.6	614.3	562.7	.1162	.3195	8
9	37.63	22.9	7.464	.1340	52.7	614.6	561.9	.1185	.3176	9
10	38.51	23.8	7.304	0.1369	53.8	614.9	561.1	0.1208	1.3157	10
11	39.40	24.7	7.148	.1399	54.9	615.2	560.3	.1231	.3137	11
12	40.31	25.6	6.996	.1429	56.0	615.5	559.5	.1254	.3118	12
13	41.24	26.5	6.847	.1460	57.1	615.8	558.7	.1277	.3099	13
14	42.18	27.5	6.703	.1492	58.2	616.1	557.9	.1300	.3081	14
15	43.14	28.4	6.562	0.1524	59.2	616.3	557.1	0.1323	1.3062	15
16	44.12	29.4	6.425	.1556	60.3	616.6	556.3	.1346	.3043	16
17	45.12	30.4	6.291	.1590	61.4	616.9	555.5	.1369	.3025	17
18	46.13	31.4	6.161	.1623	62.5	617.2	554.7	.1392	.3006	18
19	47.16	32.5	6.034	.1657	63.6	617.5	553.9	.1415	.2988	19
20	48.21	33.5	5.910	0.1692	64.7	617.8	553.1	0.1437	1.2969	20
21	49.28	34.6	5.789	.1728	65.8	618.0	552.2	.1460	.2951	21
22	50.36	35.7	5.671	.1763	66.9	618.3	551.4	.1483	.2933	22
23	51.47	36.8	5.556	.1800	68.0	618.6	550.6	.1505	.2915	23
24	52.59	37.9	5.443	.1837	69.1	618.9	549.8	.1528	.2897	24
25	53.73	39.0	5.334	0.1875	70.2	619.1	548.9	0.1551	1.2879	25
26	54.90	40.2	5.227	.1913	71.3	619.4	548.1	.1573	.2861	26
27	56.08	41.4	5.123	.1952	72.4	619.7	547.3	.1596	.2843	27
28	57.28	42.6	5.021	.1992	73.5	619.9	546.4	.1618	.2825	28
29	58.50	43.8	4.922	.2032	74.6	620.2	545.6	.1641	.2808	29
30	59.74	45.0	4.825	0.2073	75.7	620.5	544.8	0.1663	1.2790	30
31	61.00	46.3	4.730	.2114	76.8	620.7	543.9	.1686	.2773	31
32	62.29	47.6	4.637	.2156	77.9	621.0	543.1	.1708	.2755	32
33	63.59	48.9	4.547	.2199	79.0	621.2	542.2	.1730	.2738	33
34	64.91	50.2	4.459	.2243	80.1	621.5	541.4	.1753	.2721	34
35	66.26	51.6	4.373	0.2287	81.2	621.7	540.5	0.1775	1.2704	35
36	67.63	52.9	4.289	.2332	82.3	622.0	539.7	.1797	.2686	36
37	69.02	54.3	4.207	.2377	83.4	622.2	538.8	.1819	.2669	37
38	70.43	55.7	4.126	.2423	84.6	622.5	537.9	.1841	.2652	38
39	71.87	57.2	4.048	.2470	85.7	622.7	537.0	.1863	.2635	39
40	73.32	58.6	3.971	0.2518	86.8	623.0	536.2	0.1885	1.2618	40

**TABLE 1.—Saturated Ammonia: Temperature Table—Continued.**

Temp. °F. <i>t</i>	Pressure.		Volume vapor. ft./lb. <i>V</i>	Density vapor. lbs./ft. <sup>3</sup> <i>1/V</i>	Heat content.		Latent heat. Btu./lb. <i>L</i>	Entropy.		Temp. °F. <i>t</i>
	Absolute. lbs./in. <sup>2</sup> <i>p</i>	Gage. lbs./in. <sup>2</sup> <i>g. p.</i>			Liquid. Btu./lb. <i>h</i>	Vapor. Btu./lb. <i>H</i>		Liquid. Btu./lb. °F. <i>s</i>	Vapor. Btu./lb. °F. <i>S</i>	
40	73.32	58.6	3.971	0.2518	86.8	623.0	536.2	0.1885	1.2618	40
41	74.80	60.1	3.897	.2566	87.9	623.2	535.3	.1908	.2602	41
42	76.31	61.6	3.823	.2616	89.0	623.4	534.4	.1930	.2585	42
43	77.83	63.1	3.752	.2665	90.1	623.7	533.6	.1952	.2568	43
44	79.38	64.7	3.682	.2716	91.2	623.9	532.7	.1974	.2552	44
45	80.96	66.3	3.614	0.2767	92.3	624.1	531.8	0.1996	1.2535	45
46	82.55	67.9	3.547	.2819	93.5	624.4	530.9	.2018	.2519	46
47	84.18	69.5	3.481	.2872	94.6	624.6	530.0	.2040	.2502	47
48	85.82	71.1	3.418	.2926	95.7	624.8	529.1	.2062	.2486	48
49	87.49	72.8	3.355	.2981	96.8	625.0	528.2	.2063	.2469	49
50	89.19	74.5	3.294	0.3036	97.9	625.2	527.3	0.2105	1.2453	50
51	90.91	76.2	3.234	.3092	99.1	625.5	526.4	.2127	.2437	51
52	92.66	78.0	3.176	.3149	100.2	625.7	525.5	.2149	.2421	52
53	94.43	79.7	3.119	.3207	101.3	625.9	524.6	.2171	.2405	53
54	96.23	81.5	3.063	.3265	102.4	626.1	523.7	.2192	.2389	54
55	98.06	83.4	3.008	0.3325	103.5	626.3	522.8	0.2214	1.2373	55
56	99.91	85.2	2.954	.3385	104.7	626.5	521.8	.2236	.2357	56
57	101.8	87.1	2.902	.3446	105.8	626.7	520.9	.2257	.2341	57
58	103.7	89.0	2.851	.3508	106.9	626.9	520.0	.2279	.2325	58
59	105.6	90.9	2.800	.3571	108.1	627.1	519.0	.2301	.2310	59
60	107.6	92.9	2.751	0.3635	109.2	627.3	518.1	0.2322	1.2294	60
61	109.6	94.9	2.703	.3700	110.3	627.5	517.2	.2344	.2278	61
62	111.6	96.9	2.656	.3765	111.5	627.7	516.2	.2365	.2262	62
63	113.6	98.9	2.610	.3832	112.6	627.9	515.3	.2387	.2247	63
64	115.7	101.0	2.565	.3899	113.7	628.0	514.3	.2408	.2231	64
65	117.8	103.1	2.520	0.3968	114.8	628.2	513.4	0.2430	1.2216	65
66	120.0	105.3	2.477	.4037	116.0	628.4	512.4	.2451	.2201	66
67	122.1	107.4	2.435	.4108	117.1	628.6	511.5	.2473	.2186	67
68	124.3	109.6	2.393	.4179	118.3	628.8	510.5	.2494	.2170	68
69	126.5	111.8	2.352	.4251	119.4	628.9	509.5	.2515	.2155	69
70	128.8	114.1	2.312	0.4325	120.5	629.1	508.6	0.2537	1.2140	70
71	131.1	116.4	2.273	.4399	121.7	629.3	507.6	.2558	.2125	71
72	133.4	118.7	2.235	.4474	122.8	629.4	506.6	.2579	.2110	72
73	135.7	121.0	2.197	.4551	124.0	629.6	505.6	.2601	.2095	73
74	138.1	123.4	2.161	.4628	125.1	629.8	504.7	.2622	.2080	74
75	140.5	125.8	2.125	0.4707	126.2	629.9	503.7	0.2643	1.2065	75
76	143.0	128.3	2.089	.4786	127.4	630.1	502.7	.2664	.2050	76
77	145.4	130.7	2.055	.4867	128.5	630.2	501.7	.2685	.2035	77
78	147.9	133.2	2.021	.4949	129.7	630.4	500.7	.2706	.2020	78
79	150.5	135.8	1.988	.5031	130.8	630.5	499.7	.2728	.2006	79
80	153.0	138.3	1.955	0.5115	132.0	630.7	498.7	0.2749	1.1991	80
81	155.6	140.9	1.923	.5200	133.1	630.8	497.7	.2769	.1976	81
82	158.3	143.6	1.892	.5287	134.3	631.0	496.7	.2791	.1962	82
83	161.0	146.3	1.861	.5374	135.4	631.1	495.7	.2812	.1947	83
84	163.7	149.0	1.831	.5462	136.6	631.3	494.7	.2833	.1933	84
85	166.4	151.7	1.801	0.5552	137.8	631.4	493.6	0.2854	1.1918	85

TABLE 1.—Saturated Ammonia: Temperature Table—Continued.

Temp. °F. <i>t</i>	Pressure.		Volume vapor. ft. <sup>3</sup> /lb.	Density vapor. lbs./ft. <sup>3</sup> <i>1/V</i>	Heat content.		Latent heat. Btu./lb. <i>L</i>	Entropy.		Temp. °F. <i>t</i>
	Absolute. lbs./in. <sup>2</sup> <i>p</i>	Gage. lbs./in. <sup>2</sup> <i>g. p.</i>			Liquid. Btu./lb. <i>h</i>	Vapor. Btu./lb. <i>H</i>		Liquid. Btu./lb.°F. <i>s</i>	Vapor. Btu./lb.°F. <i>S</i>	
85	166.4	151.7	1.801	0.5552	137.8	631.4	493.6	0.2854	1.1918	85
86	169.2	154.5	1.772	.5643	138.9	631.5	492.6	.2875	.1904	86
87	172.0	157.3	1.744	.5735	140.1	631.7	491.6	.2895	.1889	87
88	174.8	160.1	1.716	.5828	141.2	631.8	490.6	.2917	.1875	88
89	177.7	163.0	1.688	.5923	142.4	631.9	489.5	.2937	.1860	89
90	180.6	165.9	1.661	0.6019	143.5	632.0	488.5	0.2958	1.1846	90
91	183.6	168.9	1.635	.6116	144.7	632.1	487.4	.2979	.1832	91
92	186.6	171.9	1.609	.6214	145.8	632.2	486.4	.3000	.1818	92
93	189.6	174.9	1.584	.6314	147.0	632.3	485.3	.3021	.1804	93
94	192.7	178.0	1.559	.6415	148.2	632.5	484.3	.3041	.1789	94
95	195.8	181.1	1.534	0.6517	149.4	632.6	483.2	0.3062	1.1775	95
96	198.9	184.2	1.510	.6620	150.5	632.6	482.1	.3083	.1761	96
97	202.1	187.4	1.487	.6725	151.7	632.8	481.1	.3104	.1747	97
98	205.3	190.6	1.464	.6832	152.9	632.9	480.0	.3125	.1733	98
99	208.6	193.9	1.441	.6939	154.0	632.9	478.9	.3145	.1719	99
100	211.9	197.2	1.419	0.7048	155.2	633.0	477.8	0.3166	1.1705	100
101	215.2	200.5	1.397	.7159	156.4	633.1	476.7	.3187	.1691	101
102	218.6	203.9	1.375	.7270	157.6	633.2	475.6	.3207	.1677	102
103	222.0	207.3	1.354	.7384	158.7	633.3	474.6	.3228	.1663	103
104	225.4	210.7	1.334	.7498	159.9	633.4	473.5	.3248	.1649	104
105	228.9	214.2	1.313	0.7615	161.1	633.4	472.3	0.3269	1.1635	105
106	232.5	217.8	1.293	.7732	162.3	633.5	471.2	.3289	.1621	106
107	236.0	221.3	1.274	.7852	163.5	633.6	470.1	.3310	.1607	107
108	239.7	225.0	1.254	.7972	164.6	633.6	469.0	.3330	.1593	108
109	243.3	228.6	1.235	.8095	165.8	633.7	467.9	.3351	.1580	109
110	247.0	232.3	1.217	0.8219	167.0	633.7	466.7	0.3372	1.1566	110
111	250.8	236.1	1.198	.8344	168.2	633.8	465.6	.3392	.1552	111
112	254.5	239.8	1.180	.8471	169.4	633.8	464.4	.3413	.1538	112
113	258.4	243.7	1.163	.8600	170.6	633.9	463.3	.3433	.1524	113
114	262.2	247.5	1.145	.8730	171.8	633.9	462.1	.3453	.1510	114
115	266.2	251.5	1.128	0.8862	173.0	633.9	460.9	0.3474	1.1497	115
116	270.1	255.4	1.112	.8996	174.2	634.0	459.8	.3495	.1483	116
117	274.1	259.4	1.095	.9132	175.4	634.0	458.6	.3515	.1469	117
118	278.2	263.5	1.079	.9269	176.6	634.0	457.4	.3535	.1455	118
119	282.3	267.6	1.063	.9408	177.8	634.0	456.2	.3556	.1441	119
120	286.4	271.7	1.047	0.9549	179.0	634.0	455.0	0.3576	1.1427	120
121	290.6	275.9	1.032	.9692	180.2	634.0	453.8	.3597	.1414	121
122	294.8	280.1	1.017	.9837	181.4	634.0	452.6	.3618	.1400	122
123	299.1	284.4	1.002	.9983	182.6	634.0	451.4	.3638	.1386	123
124	303.4	288.7	0.987	1.0132	183.9	634.0	450.1	.3659	.1372	124
125	307.8	293.1	0.973	1.028	185.1	634.0	448.9	0.3679	1.1358	125

TABLE 2.—Saturated Ammonia: Absolute Pressure Table.

Pressure (abs.), lbs./in. <sup>2</sup>	Temp. °F.	Volume vapor, ft. <sup>3</sup> /lb.	Density vapor, lbs./ft. <sup>3</sup>	Heat content.		Latent heat, Btu./lb.	Entropy.			Pressure (abs.), lbs./in. <sup>2</sup>
				Liquid, Btu./lb.	Vapor, Btu./lb.		Liquid, Btu./lb. °F.	Evap. Btu./lb. °F.	Vapor, Btu./lb. °F.	
<i>p</i>	<i>t</i>	<i>V</i>	<i>1/V</i>	<i>h</i>	<i>H</i>	<i>L</i>	<i>s</i>	<i>L/T</i>	<i>S</i>	<i>p</i>
5.0	-63.11	49.31	0.02029	-24.5	588.3	612.8	-0.0599	1.5456	1.4857	5.0
5.5	-60.27	45.11	.02217	-21.5	589.5	611.0	-.0624	.5301	.4777	5.5
6.0	-57.64	41.59	.02405	-18.7	590.6	609.3	-.0455	.5158	.4703	6.0
6.5	-55.18	38.59	.02591	-16.1	591.6	607.7	-.0590	.5026	.4636	6.5
7.0	-52.88	36.01	.02777	-13.7	592.5	606.2	-.0380	.4904	.4574	7.0
7.5	-50.70	33.77	0.02962	-11.3	593.4	604.7	-0.0274	1.4790	1.4516	7.5
8.0	-48.64	31.79	.03146	-9.2	594.2	603.4	-.0221	.4683	.4462	8.0
8.5	-46.69	30.04	.03329	-7.1	595.0	602.1	-.0171	.4582	.4411	8.5
9.0	-44.83	28.48	.03511	-5.1	595.7	600.8	-.0123	.4486	.4363	9.0
9.5	-43.05	27.08	.03693	-3.2	596.4	599.6	-.0077	.4396	.4319	9.5
10.0	-41.34	25.81	0.03874	-1.4	597.1	598.5	-0.0034	1.4310	1.4276	10.0
10.5	-39.71	24.66	.04055	+0.3	597.7	597.4	+.0007	.4228	.4235	10.5
11.0	-38.14	23.61	.04235	2.0	598.3	596.3	.0047	.4149	.4196	11.0
11.5	-36.62	22.65	.04414	3.6	598.9	595.3	.0085	.4074	.4159	11.5
12.0	-35.16	21.77	.04593	5.1	599.4	594.3	.0122	.4002	.4124	12.0
12.5	-33.74	20.96	0.04772	6.7	600.0	593.3	0.0157	1.3933	1.4090	12.5
13.0	-32.37	20.20	.04950	8.1	600.5	592.4	.0191	.3866	.4057	13.0
13.5	-31.05	19.50	.05128	9.6	601.0	591.4	.0225	.3801	.4028	13.5
14.0	-29.76	18.85	.05305	10.9	601.4	590.5	.0257	.3739	.3996	14.0
14.5	-28.51	18.24	.05482	12.2	601.9	589.7	.0288	.3679	.3967	14.5
15.0	-27.29	17.67	0.05658	13.6	602.4	588.8	0.0318	1.3620	1.3938	15.0
15.5	-26.11	17.14	.05834	14.8	602.8	588.0	.0347	.3564	.3911	15.5
16.0	-24.95	16.64	.06010	16.0	603.2	587.2	.0375	.3510	.3885	16.0
16.5	-23.83	16.17	.06186	17.2	603.6	586.4	.0403	.3456	.3859	16.5
17.0	-22.73	15.72	.06361	18.4	604.0	585.6	.0430	.3405	.3835	17.0
17.5	-21.66	15.30	0.06535	19.6	604.4	584.8	0.0456	1.3354	1.3810	17.5
18.0	-20.61	14.90	.06710	20.7	604.8	584.1	.0482	.3305	.3787	18.0
18.5	-19.59	14.53	.06884	21.8	605.1	583.3	.0507	.3258	.3765	18.5
19.0	-18.58	14.17	.07058	22.9	605.5	582.6	.0531	.3211	.3742	19.0
19.5	-17.60	13.83	.07232	23.9	605.8	581.9	.0555	.3166	.3721	19.5
20.0	-16.64	13.50	0.07406	25.0	606.2	581.2	0.0578	1.3122	1.3700	20.0
20.5	-15.70	13.20	.07578	26.0	606.5	580.5	.0601	.3078	.3679	20.5
21.0	-14.78	12.90	.07751	27.0	606.8	579.8	.0623	.3036	.3659	21.0
21.5	-13.87	12.62	.07924	27.9	607.1	579.2	.0645	.2995	.3640	21.5
22.0	-12.98	12.35	.08096	28.9	607.4	578.5	.0666	.2955	.3621	22.0
22.5	-12.11	12.09	0.08268	29.8	607.7	577.9	0.0687	1.2915	1.3602	22.5
23.0	-11.25	11.85	.08440	30.8	608.1	577.3	.0708	.2876	.3584	23.0
23.5	-10.41	11.61	.08612	31.7	608.3	576.6	.0728	.2838	.3566	23.5
24.0	-9.58	11.39	.08783	32.6	608.6	576.0	.0748	.2801	.3549	24.0
24.5	-8.76	11.17	.08955	33.5	608.9	575.4	.0768	.2764	.3532	24.5
25.0	-7.96	10.96	0.09126	34.3	609.1	574.8	0.0787	1.2728	1.3515	25.0
25.5	-7.17	10.76	.09297	35.2	609.4	574.2	.0805	.2693	.3498	25.5
26.0	-6.39	10.56	.09468	36.0	609.7	573.7	.0824	.2658	.3482	26.0
26.5	-5.63	10.38	.09638	36.8	609.9	573.1	.0842	.2625	.3467	26.5
27.0	-4.87	10.20	.09809	37.7	610.2	572.5	.0860	.2591	.3451	27.0
27.5	-4.13	10.02	0.09979	38.4	610.4	572.0	0.0878	1.2558	1.3436	27.5
28.0	-3.40	9.853	.1015	39.3	610.7	571.4	.0895	.2526	.3421	28.0
28.5	-2.68	9.691	.1032	40.0	610.9	570.9	.0912	.2494	.3406	28.5
29.0	-1.97	9.534	.1049	40.8	611.1	570.3	.0929	.2463	.3392	29.0
29.5	-1.27	9.383	.1066	41.6	611.4	569.8	.0945	.2433	.3378	29.5
30.0	-0.57	9.236	0.1083	42.3	611.6	569.3	0.0962	1.2402	1.3364	30.0

TABLE 2.—Saturated Ammonia: Absolute Pressure Table—Continued.

Pressure (abs.), lbs./in. <sup>2</sup>	Temp. °F.	Volume ft. <sup>3</sup> /lb.	Density vapor, lbs./ft. <sup>3</sup>	Heat content.		Latent heat, Btu./lb.	Entropy.			Pressure (abs.), lbs./in. <sup>2</sup>
				Liquid, Btu./lb.	Vapor, Btu./lb.		Liquid, Btu./lb. °F.	Evap. Btu./lb. °F.	Vapor, Btu./lb. °F.	
<i>p</i>	<i>t</i>	<i>V</i>	<i>1/V</i>	<i>h</i>	<i>H</i>	<i>L</i>	<i>s</i>	<i>L/T</i>	<i>S</i>	<i>p</i>
30	-0.57	9.236	0.1083	42.3	611.6	569.3	0.0962	1.2402	1.3364	80
31	+0.79	8.955	.1117	43.8	612.0	568.2	.0993	.2343	.3336	31
32	2.11	8.693	.1150	45.2	612.4	567.2	.1024	.2286	.3310	32
33	3.40	8.445	.1184	46.6	612.8	566.2	.1055	.2230	.3285	33
34	4.66	8.211	.1218	48.0	613.2	565.2	.1084	.2176	.3260	34
35	5.89	7.991	0.1251	49.3	613.6	564.3	0.1113	1.2123	1.3236	35
36	7.09	7.782	.1285	50.6	614.0	563.4	.1141	.2072	.3213	36
37	8.27	7.584	.1319	51.9	614.3	562.4	.1168	.2022	.3190	37
38	9.42	7.396	.1352	53.2	614.7	561.5	.1195	.1973	.3168	38
39	10.55	7.217	.1386	54.4	615.0	560.6	.1221	.1925	.3146	39
40	11.66	7.047	0.1419	55.6	615.4	559.8	0.1246	1.1879	1.3125	40
41	12.74	6.885	.1452	56.8	615.7	558.9	.1271	.1833	.3104	41
42	13.81	6.731	.1486	57.9	616.0	558.1	.1296	.1788	.3084	42
43	14.85	6.583	.1519	59.1	616.3	557.2	.1320	.1745	.3065	43
44	15.88	6.442	.1552	60.2	616.6	556.4	.1343	.1703	.3046	44
45	16.88	6.307	0.1586	61.3	616.9	555.6	0.1366	1.1661	1.3027	45
46	17.87	6.177	.1619	62.4	617.2	554.8	.1389	.1620	.3009	46
47	18.84	6.053	.1652	63.4	617.4	554.0	.1411	.1580	.2991	47
48	19.80	5.934	.1685	64.5	617.7	553.2	.1433	.1540	.2973	48
49	20.74	5.820	.1718	65.5	618.0	552.5	.1454	.1502	.2956	49
50	21.67	5.710	0.1751	66.5	618.2	551.7	0.1475	1.1464	1.2939	50
51	22.58	5.604	.1785	67.5	618.5	551.0	.1496	.1427	.2923	51
52	23.48	5.502	.1818	68.5	618.7	550.2	.1516	.1390	.2906	52
53	24.36	5.404	.1851	69.5	619.0	549.5	.1536	.1354	.2890	53
54	25.23	5.309	.1884	70.4	619.2	548.8	.1556	.1319	.2875	54
55	26.09	5.218	0.1917	71.4	619.4	548.0	0.1575	1.1284	1.2859	55
56	26.94	5.129	.1950	72.3	619.7	547.4	.1594	.1250	.2844	56
57	27.77	5.044	.1983	73.3	619.9	546.6	.1613	.1217	.2830	57
58	28.59	4.962	.2015	74.2	620.1	545.9	.1631	.1184	.2815	58
59	29.41	4.882	.2048	75.0	620.3	545.3	.1650	.1151	.2801	59
60	30.21	4.805	0.2081	75.9	620.5	544.6	0.1668	1.1119	1.2787	60
61	31.00	4.730	.2114	76.8	620.7	543.9	.1685	.1088	.2773	61
62	31.78	4.658	.2147	77.7	620.9	543.2	.1703	.1056	.2759	62
63	32.55	4.588	.2180	78.5	621.1	542.6	.1720	.1026	.2746	63
64	33.31	4.519	.2213	79.4	621.3	541.9	.1737	.0996	.2733	64
65	34.06	4.453	0.2245	80.2	621.5	541.3	0.1754	1.0966	1.2720	65
66	34.81	4.389	.2278	81.0	621.7	540.7	.1770	.0937	.2707	66
67	35.54	4.327	.2311	81.8	621.9	540.1	.1787	.0907	.2694	67
68	36.27	4.267	.2344	82.6	622.0	539.4	.1803	.0879	.2682	68
69	36.99	4.208	.2377	83.4	622.2	538.8	.1819	.0851	.2670	69
70	37.70	4.151	0.2409	84.2	622.4	538.2	0.1835	1.0823	1.2658	70
71	38.40	4.095	.2442	85.0	622.6	537.6	.1850	.0795	.2645	71
72	39.09	4.041	.2475	85.8	622.8	537.0	.1866	.0768	.2634	72
73	39.78	3.988	.2507	86.5	622.9	536.4	.1881	.0741	.2622	73
74	40.46	3.937	.2540	87.3	623.1	535.8	.1896	.0715	.2611	74
75	41.13	3.887	0.2573	88.0	623.2	535.2	0.1910	1.0689	1.2599	75
76	41.80	3.838	.2606	88.8	623.4	534.6	.1925	.0663	.2588	76
77	42.46	3.790	.2638	89.5	623.5	534.0	.1940	.0637	.2577	77
78	43.11	3.744	.2671	90.2	623.7	533.5	.1954	.0612	.2566	78
79	43.76	3.699	.2704	90.9	623.8	532.9	.1968	.0587	.2555	79
80	44.40	3.655	0.2736	91.7	624.0	532.3	0.1982	1.0563	1.2545	80

TABLE 2.—Saturated Ammonia: Absolute Pressure Table—Continued.

Pressure (abs.). lbs./in. <sup>2</sup>	Temp. °F.	Volume vapor. ft. <sup>3</sup> /lb.	Density vapor. lbs./ft. <sup>3</sup>	Heat content.		Latent heat. Btu./lb.	Entropy.			Pressure (abs.). lbs./in. <sup>2</sup>
				Liquid. Btu./lb.	Vapor. Btu./lb.		Liquid. Btu./lb. °F.	Evap. Btu./lb. °F.	Vapor. Btu./lb. °F.	
<i>p</i>	<i>t</i>	<i>V</i>	<i>1/V</i>	<i>h</i>	<i>H</i>	<i>L</i>	<i>s</i>	<i>L/T</i>	<i>S</i>	<i>p</i>
<b>80</b>	44. 40	3. 655	0. 2736	91. 7	624. 0	532. 3	0. 1982	1. 0563	1. 2545	<b>80</b>
81	45. 03	3. 612	. 2769	92. 4	624. 1	531. 7	. 1996	. 0538	. 2534	81
82	45. 66	3. 570	. 2801	93. 1	624. 3	531. 2	. 2010	. 0514	. 2524	82
83	46. 28	3. 528	. 2834	93. 8	624. 4	530. 6	. 2024	. 0490	. 2514	83
84	46. 89	3. 488	. 2867	94. 5	624. 6	530. 1	. 2037	. 0467	. 2504	84
<b>85</b>	47. 50	3. 449	0. 2899	95. 1	624. 7	529. 6	0. 2051	1. 0443	1. 2494	<b>85</b>
86	48. 11	3. 411	. 2932	95. 8	624. 8	529. 0	. 2064	. 0420	. 2484	86
87	48. 71	3. 373	. 2964	96. 5	625. 0	528. 5	. 2077	. 0397	. 2474	87
88	49. 30	3. 337	. 2997	97. 2	625. 1	527. 9	. 2090	. 0375	. 2465	88
89	49. 89	3. 301	. 3030	97. 8	625. 2	527. 4	. 2103	. 0352	. 2455	89
<b>90</b>	50. 47	3. 266	0. 3062	98. 4	625. 3	526. 9	0. 2115	1. 0330	1. 2445	<b>90</b>
91	51. 05	3. 231	. 3095	99. 1	625. 5	526. 4	. 2128	. 0308	. 2436	91
92	51. 62	3. 198	. 3127	99. 8	625. 6	525. 8	. 2141	. 0286	. 2427	92
93	52. 19	3. 165	. 3160	100. 4	625. 7	525. 3	. 2153	. 0265	. 2418	93
94	52. 76	3. 132	. 3192	101. 0	625. 8	524. 8	. 2165	. 0243	. 2408	94
<b>95</b>	53. 32	3. 101	0. 3225	101. 6	625. 9	524. 3	0. 2177	1. 0222	1. 2399	<b>95</b>
96	53. 87	3. 070	. 3258	102. 3	626. 1	523. 8	. 2190	. 0201	. 2391	96
97	54. 42	3. 039	. 3290	102. 9	626. 2	523. 3	. 2201	. 0181	. 2382	97
98	54. 97	3. 010	. 3323	103. 5	626. 3	522. 8	. 2213	. 0160	. 2373	98
99	55. 51	2. 980	. 3355	104. 1	626. 4	522. 3	. 2225	. 0140	. 2365	99
<b>100</b>	56. 05	2. 952	0. 3388	104. 7	626. 5	521. 8	0. 2237	1. 0119	1. 2356	<b>100</b>
102	57. 11	2. 896	. 3453	105. 9	626. 7	520. 8	. 2260	. 0079	. 2339	102
104	58. 16	2. 843	. 3518	107. 1	626. 9	519. 8	. 2282	. 0041	. 2323	104
106	59. 19	2. 791	. 3583	108. 3	627. 1	518. 8	. 2305	1. 0002	. 2307	106
108	60. 21	2. 741	. 3648	109. 4	627. 3	517. 9	. 2327	0. 9964	. 2291	108
<b>110</b>	61. 21	2. 693	0. 3713	110. 5	627. 5	517. 0	0. 2348	0. 9927	1. 2275	<b>110</b>
112	62. 20	2. 647	. 3778	111. 7	627. 7	516. 0	. 2369	. 9890	. 2259	112
114	63. 17	2. 602	. 3843	112. 8	627. 9	515. 1	. 2390	. 9854	. 2244	114
116	64. 13	2. 559	. 3909	113. 9	628. 1	514. 2	. 2411	. 9819	. 2230	116
118	65. 08	2. 517	. 3974	114. 9	628. 2	513. 3	. 2431	. 9784	. 2215	118
<b>120</b>	66. 02	2. 476	0. 4039	116. 0	628. 4	512. 4	0. 2452	0. 9749	1. 2201	<b>120</b>
122	66. 94	2. 437	. 4104	117. 1	628. 6	511. 5	. 2471	. 9715	. 2186	122
124	67. 86	2. 399	. 4169	118. 1	628. 7	510. 6	. 2491	. 9682	. 2173	124
126	68. 76	2. 362	. 4234	119. 1	628. 9	509. 8	. 2510	. 9649	. 2159	126
128	69. 65	2. 326	. 4299	120. 1	629. 0	508. 9	. 2529	. 9616	. 2145	128
<b>130</b>	70. 53	2. 291	0. 4364	121. 1	629. 2	508. 1	0. 2548	0. 9584	1. 2132	<b>130</b>
132	71. 40	2. 258	. 4429	122. 1	629. 3	507. 2	. 2567	. 9552	. 2119	132
134	72. 26	2. 225	. 4494	123. 1	629. 5	506. 4	. 2585	. 9521	. 2106	134
136	73. 11	2. 193	. 4559	124. 1	629. 6	505. 5	. 2603	. 9490	. 2093	136
138	73. 95	2. 162	. 4624	125. 1	629. 8	504. 7	. 2621	. 9460	. 2081	138
<b>140</b>	74. 79	2. 132	0. 4690	126. 0	629. 9	503. 9	0. 2638	0. 9430	1. 2068	<b>140</b>
142	75. 61	2. 103	. 4755	126. 9	630. 0	503. 1	. 2656	. 9400	. 2056	142
144	76. 42	2. 075	. 4820	127. 9	630. 2	502. 3	. 2673	. 9371	. 2044	144
146	77. 23	2. 047	. 4885	128. 8	630. 3	501. 5	. 2690	. 9342	. 2032	146
148	78. 03	2. 020	. 4951	129. 7	630. 4	500. 7	. 2707	. 9313	. 2020	148
<b>150</b>	78. 81	1. 994	0. 5016	130. 6	630. 5	499. 9	0. 2724	0. 9285	1. 2009	<b>150</b>

TABLE 2.—Saturated Ammonia: Absolute Pressure Table—Continued.

Pressure (abs.), lbs./in. <sup>2</sup>	Temp. °F.	Volume vapor, ft. <sup>3</sup> /lb.	Density vapor, lbs./ft. <sup>3</sup>	Heat content.		Latent heat, Btu./lb.	Entropy.			Pressure (abs.), lbs./in. <sup>2</sup>
				Liquid, Btu./lb.	Vapor, Btu./lb.		Liquid, Btu./lb. °F.	Evap., Btu./lb. °F.	Vapor, Btu./lb. °F.	
<i>p</i>	<i>t</i>	<i>V</i>	<i>1/V</i>	<i>h</i>	<i>H</i>	<i>L</i>	<i>s</i>	<i>L/T</i>	<i>S</i>	<i>p</i>
<b>150</b>	78. 81	1. 994	0. 5016	130. 6	630. 5	499. 9	0. 2724	0. 9285	1. 2009	<b>150</b>
152	79. 60	1. 968	. 5081	131. 5	630. 6	499. 1	. 2740	. 9257	. 1997	152
154	80. 37	1. 943	. 5147	132. 4	630. 7	498. 3	. 2756	. 9229	. 1985	154
156	81. 13	1. 919	. 5212	133. 3	630. 9	497. 6	. 2772	. 9202	. 1974	156
158	81. 89	1. 895	. 5277	134. 2	631. 0	496. 8	. 2788	. 9175	. 1963	158
<b>160</b>	82. 64	1. 872	0. 5343	135. 0	631. 1	496. 1	0. 2804	0. 9148	1. 1952	<b>160</b>
162	83. 39	1. 849	. 5408	135. 9	631. 2	495. 3	. 2820	. 9122	. 1942	162
164	84. 12	1. 827	. 5473	136. 8	631. 3	494. 5	. 2835	. 9096	. 1931	164
166	84. 85	1. 805	. 5539	137. 6	631. 4	493. 8	. 2850	. 9070	. 1920	166
168	85. 57	1. 784	. 5604	138. 4	631. 5	493. 1	. 2866	. 9044	. 1910	168
<b>170</b>	86. 29	1. 764	0. 5670	139. 3	631. 6	492. 3	0. 2881	0. 9019	1. 1900	<b>170</b>
172	87. 00	1. 744	. 5735	140. 1	631. 7	491. 6	. 2895	. 8994	. 1889	172
174	87. 71	1. 724	. 5801	140. 9	631. 7	490. 8	. 2910	. 8969	. 1879	174
176	88. 40	1. 705	. 5866	141. 7	631. 8	490. 1	. 2925	. 8944	. 1869	176
178	89. 10	1. 686	. 5932	142. 5	631. 9	489. 4	. 2939	. 8920	. 1859	178
<b>180</b>	89. 78	1. 667	0. 5998	143. 3	632. 0	488. 7	0. 2954	0. 8896	1. 1850	<b>180</b>
182	90. 46	1. 649	. 6063	144. 1	632. 1	488. 0	. 2968	. 8872	. 1840	182
184	91. 14	1. 632	. 6129	144. 8	632. 1	487. 3	. 2982	. 8848	. 1830	184
186	91. 80	1. 614	. 6195	145. 6	632. 2	486. 6	. 2996	. 8825	. 1821	186
188	92. 47	1. 597	. 6261	146. 4	632. 3	485. 9	. 3010	. 8801	. 1811	188
<b>190</b>	93. 13	1. 581	0. 6326	147. 2	632. 4	485. 2	0. 3024	0. 8778	1. 1802	<b>190</b>
192	93. 78	1. 564	. 6392	147. 9	632. 4	484. 5	. 3037	. 8755	. 1792	192
194	94. 43	1. 548	. 6458	148. 7	632. 5	483. 8	. 3050	. 8733	. 1783	194
196	95. 07	1. 533	. 6524	149. 5	632. 6	483. 1	. 3064	. 8710	. 1774	196
198	95. 71	1. 517	. 6590	150. 2	632. 6	482. 4	. 3077	. 8688	. 1765	198
<b>200</b>	96. 34	1. 502	0. 6656	150. 9	632. 7	481. 8	0. 3090	1. 8666	1. 1756	<b>200</b>
205	97. 90	1. 466	. 6821	152. 7	632. 8	480. 1	. 3122	. 8612	. 1734	205
210	99. 43	1. 431	. 6986	154. 6	633. 0	478. 4	. 3154	. 8559	. 1713	210
215	100. 94	1. 398	. 7152	156. 3	633. 1	476. 8	. 3185	. 8507	. 1692	215
220	102. 42	1. 367	. 7318	158. 0	633. 2	475. 2	. 3216	. 8455	. 1671	220
<b>225</b>	103. 87	1. 336	0. 7484	159. 7	633. 3	473. 6	0. 3246	0. 8405	1. 1651	<b>225</b>
230	105. 30	1. 307	. 7650	161. 4	633. 4	472. 0	. 3275	. 8356	. 1631	230
235	106. 71	1. 279	. 7817	163. 1	633. 5	470. 4	. 3304	. 8307	. 1611	235
240	108. 09	1. 253	. 7984	164. 7	633. 6	468. 9	. 3332	. 8260	. 1592	240
245	109. 46	1. 227	. 8151	166. 4	633. 7	467. 3	. 3360	. 8213	. 1573	245
<b>250</b>	110. 80	1. 202	0. 8319	168. 0	633. 8	465. 8	0. 3388	0. 8167	1. 1555	<b>250</b>
255	112. 12	1. 178	. 8487	169. 5	633. 8	464. 3	. 3415	. 8121	. 1536	255
260	113. 42	1. 155	. 8655	171. 1	633. 9	462. 8	. 3441	. 8077	. 1518	260
265	114. 71	1. 133	. 8824	172. 6	633. 9	461. 3	. 3468	. 8033	. 1501	265
270	115. 97	1. 112	. 8993	174. 1	633. 9	459. 8	. 3494	. 7989	. 1483	270
<b>275</b>	117. 22	1. 091	0. 9162	175. 6	634. 0	458. 4	0. 3519	0. 7947	1. 1466	<b>275</b>
280	118. 45	1. 072	. 9332	177. 1	634. 0	456. 9	. 3545	. 7904	. 1449	280
285	119. 66	1. 052	. 9502	178. 6	634. 0	455. 4	. 3569	. 7863	. 1432	285
290	120. 86	1. 034	. 9672	180. 0	634. 0	454. 0	. 3594	. 7821	. 1415	290
295	122. 05	1. 016	. 9843	181. 5	634. 0	452. 5	. 3618	. 7781	. 1399	295
<b>300</b>	123. 21	0. 999	1. 0015	182. 9	634. 0	451. 1	0. 3642	0. 7741	1. 1383	<b>300</b>

TABLE 3.—Saturated Ammonia: Gauge Pressure Table.

Pressure. (gauge). lbs./in. <sup>2</sup>	Temp. ° F.	Volume vapor. ft. <sup>3</sup> /lb.	Density vapor. lbs./ft. <sup>3</sup>	Heat content.		Latent heat. Btu./lb.	Entropy.			Pressure (gauge). lbs./in. <sup>2</sup>
				Liquid. Btu./lb.	Vapor. Btu./lb.		Liquid. Btu./lb.°F.	Evap. Btu./lb.°F.	Vapor. Btu./lb.°F.	
<i>g. p.</i>	<i>t</i>	<i>V</i>	<i>1/V</i>	<i>h</i>	<i>H</i>	<i>L</i>	<i>s</i>	<i>L/T</i>	<i>S</i>	<i>g. p.</i>
20*	-63.9	50.5	0.0198	-25.3	588.0	613.3	-0.062	1.550	1.488	20*
19*	-61.0	46.2	.0217	-22.3	589.2	611.5	-.055	.535	.480	19*
18*	-58.4	42.6	.0235	-19.5	590.3	609.8	-.048	.521	.473	18*
17*	-55.9	39.5	.0253	-16.9	591.3	608.2	-.041	.507	.466	17*
16*	-53.6	36.8	.0272	-14.5	592.2	606.7	-.035	.495	.460	16*
15*	-51.4	34.5	0.0290	-12.2	593.1	605.3	-0.029	1.483	1.454	15*
14*	-49.4	32.5	.0308	-10.0	593.9	603.9	-.023	.472	.449	14*
13*	-47.4	30.7	.0326	-7.9	594.7	602.6	-.019	.462	.443	13*
12*	-45.6	29.1	.0344	-5.9	595.4	601.3	-.014	.452	.438	12*
11*	-43.8	27.6	.0362	-4.0	596.1	600.1	-.010	.443	.433	11*
10*	-42.1	26.3	0.0380	-2.2	596.8	599.0	-0.005	1.434	1.429	10*
9*	-40.4	25.2	.0397	-0.5	597.4	597.9	-.001	.426	.425	9*
8*	-38.9	24.1	.0415	+ 1.2	598.0	596.8	+ .003	.418	.421	8*
7*	-37.3	23.1	.0433	2.8	598.6	595.8	.007	.411	.418	7*
6*	-35.9	22.2	.0450	4.4	599.1	594.7	.010	.405	.415	6*
5*	-34.5	21.4	0.0468	5.9	599.6	593.7	0.014	1.397	1.411	5*
4*	-33.1	20.6	.0485	7.4	600.2	592.8	.017	.390	.407	4*
3*	-31.8	19.9	.0503	8.8	600.7	591.9	.020	.384	.404	3*
2*	-30.5	19.2	.0520	10.2	601.2	591.0	.024	.377	.401	2*
1*	-29.2	18.6	.0538	11.5	601.6	590.1	.027	.371	.398	1*
0	-28.0	18.0	0.0555	12.8	602.1	589.3	0.030	1.366	1.396	0
1	-25.6	16.9	.0590	15.4	603.0	587.6	.036	.354	.390	1
2	-23.4	16.0	.0626	17.8	603.8	586.0	.041	.344	.385	2
3	-21.2	15.1	.0661	20.1	604.6	584.5	.047	.333	.380	3
4	-19.2	14.4	.0695	22.3	605.3	583.0	.052	.324	.376	4
5	-17.2	13.7	0.0730	24.4	606.0	581.6	0.056	1.315	1.371	5
6	-15.3	13.1	.0765	26.4	606.6	580.2	.061	.306	.367	6
7	-13.5	12.5	.0799	28.4	607.3	578.9	.065	.298	.363	7
8	-11.8	12.0	.0834	30.3	607.9	577.6	.070	.290	.360	8
9	-10.1	11.5	.0868	32.1	608.4	576.3	.074	.282	.356	9
10	- 8.4	11.1	0.0902	33.8	609.0	575.2	0.078	1.275	1.353	10
11	- 6.9	10.7	.0937	35.5	609.5	574.0	.081	.268	.349	11
12	- 5.3	10.3	.0971	37.1	610.0	572.9	.085	.261	.346	12
13	- 3.8	9.96	.100	38.8	610.5	571.7	.088	.255	.343	13
14	- 2.4	9.63	.104	40.4	611.0	570.6	.092	.248	.340	14
15	- 1.0	9.32	0.107	41.9	611.4	569.5	0.095	1.242	1.337	15
16	+ 0.4	9.04	.111	43.4	611.9	568.5	.098	.236	.334	16
17	1.7	8.78	.114	44.8	612.3	567.5	.101	.230	.331	17
18	3.0	8.53	.117	46.2	612.7	566.5	.104	.225	.329	18
19	4.3	8.28	.121	47.6	613.1	565.5	.107	.219	.326	19
20	5.5	8.06	0.124	48.9	613.5	564.6	0.110	1.214	1.324	20
21	6.7	7.85	.127	50.2	613.9	563.7	.113	.209	.322	21
22	7.9	7.65	.131	51.5	614.2	562.7	.116	.204	.320	22
23	9.1	7.46	.134	52.8	614.6	561.8	.119	.199	.318	23
24	10.2	7.28	.138	54.0	614.9	560.9	.121	.194	.315	24
25	11.3	7.11	0.141	55.3	615.3	560.0	0.124	1.189	1.313	25
26	12.4	6.94	.144	56.5	615.6	559.1	.126	.185	.311	26
27	13.5	6.78	.148	57.6	615.9	558.3	.129	.180	.309	27
28	14.5	6.63	.151	58.8	616.2	557.4	.131	.176	.307	28
29	15.6	6.49	.154	59.9	616.5	556.6	.134	.171	.305	29
30	16.6	6.35	0.158	61.0	616.8	555.8	0.136	1.167	1.303	30

\* Inches of mercury below one standard atmosphere (29.92 in.).

TABLE 3.—Saturated Ammonia: Gage Pressure Table—Continued.

Pressure. (gage). lbs./in. <sup>2</sup>	Temp. ° F.	Volume vapor. ft. <sup>3</sup> /lb.	Density vapor. lbs./ft. <sup>3</sup>	Heat content.		Latent heat. Btu./lb.	Entropy.			Pressure (gage). lbs./in. <sup>2</sup>
				Liquid. Btu./lb.	Vapor. Btu./lb.		Liquid. Btu./lb.°F.	Evap. Btu./lb.°F.	Vapor. Btu./lb.°F.	
<i>g. p.</i>	<i>t</i>	<i>V</i>	<i>1/V</i>	<i>h</i>	<i>H</i>	<i>L</i>	<i>s</i>	<i>L/T</i>	<i>S</i>	<i>g. p.</i>
30	16.6	6.35	0.158	61.0	616.8	555.8	0.136	1.167	1.303	30
31	17.6	6.22	.161	62.1	617.1	555.0	.138	.163	.301	31
32	18.6	6.09	.164	63.2	617.4	554.2	.140	.159	.299	32
32	19.5	5.97	.168	64.2	617.6	553.4	.143	.155	.298	33
34	20.5	5.85	.171	65.3	617.9	552.6	.145	.151	.296	34
35	21.4	5.74	0.174	66.3	618.2	551.9	0.147	1.148	1.295	35
36	22.3	5.64	.177	67.3	618.4	551.1	.149	.144	.293	36
37	23.2	5.54	.181	68.3	618.7	550.4	.151	.140	.291	37
38	24.1	5.44	.184	69.2	618.9	549.7	.153	.137	.290	38
39	25.0	5.34	.187	70.2	619.1	548.9	.155	.133	.288	39
40	25.8	5.25	0.191	71.2	619.4	548.2	0.157	1.130	1.287	40
41	26.7	5.16	.194	72.1	619.6	547.5	.159	.126	.285	41
42	27.5	5.07	.197	73.0	619.8	546.8	.161	.123	.284	42
43	28.3	4.99	.201	73.9	620.0	546.1	.163	.119	.282	43
44	29.2	4.91	.204	74.8	620.3	545.5	.164	.116	.280	44
45	30.0	4.83	0.207	75.7	620.5	544.8	0.166	1.113	1.279	45
46	30.8	4.76	.210	76.6	620.7	544.1	.168	.110	.278	46
47	31.5	4.68	.214	77.4	620.9	543.5	.170	.107	.277	47
48	32.3	4.61	.217	78.3	621.1	542.8	.171	.104	.275	48
49	33.1	4.54	.220	79.1	621.3	542.2	.173	.101	.274	49
50	33.8	4.48	0.224	80.0	621.5	541.5	0.175	1.098	1.273	50
51	34.6	4.41	.227	80.8	621.7	540.9	.177	.095	.272	51
52	35.3	4.35	.230	81.6	621.8	540.2	.178	.092	.270	52
53	36.1	4.29	.233	82.4	622.0	539.6	.180	.089	.269	53
54	36.8	4.23	.237	83.2	622.2	539.0	.181	.086	.267	54
55	37.5	4.17	0.240	84.0	622.4	538.4	0.183	1.083	1.266	55
56	38.2	4.12	.243	84.8	622.5	537.7	.185	.080	.265	56
57	38.9	4.06	.246	85.6	622.7	537.1	.186	.078	.264	57
58	39.6	4.01	.250	86.3	622.9	536.6	.188	.075	.263	58
59	40.3	3.96	.253	87.0	623.0	536.0	.189	.072	.261	59
60	40.9	3.91	0.256	87.8	623.2	535.4	0.191	1.069	1.260	60
61	41.6	3.86	.260	88.6	623.4	534.8	.192	.067	.259	61
62	42.3	3.81	.263	89.3	623.5	534.2	.194	.064	.258	62
63	42.9	3.77	.266	90.0	623.7	533.7	.195	.062	.257	63
64	43.6	3.72	.269	90.7	623.8	533.1	.196	.060	.256	64
65	44.2	3.67	0.273	91.5	624.0	532.5	0.198	1.057	1.255	65
66	44.8	3.63	.276	92.2	624.1	531.9	.199	.055	.254	66
67	45.5	3.59	.279	92.9	624.2	531.3	.201	.052	.253	67
68	46.1	3.55	.282	93.6	624.4	530.8	.202	.050	.252	68
69	46.7	3.51	.286	94.3	624.5	530.2	.203	.048	.251	69
70	47.3	3.47	0.289	94.9	624.6	529.7	0.205	1.045	1.250	70
71	47.9	3.43	.292	95.6	624.8	529.2	.206	.043	.249	71
72	48.5	3.39	.295	96.3	624.9	528.6	.207	.041	.248	72
73	49.1	3.35	.299	97.0	625.1	528.1	.209	.038	.247	73
74	49.7	3.32	.302	97.6	625.2	527.6	.210	.036	.246	74
75	50.3	3.28	0.305	98.3	625.3	527.0	0.211	1.034	1.245	75
76	50.9	3.24	.308	98.9	625.4	526.5	.212	.032	.244	76
77	51.5	3.21	.312	99.5	625.5	526.0	.214	.029	.243	77
78	52.0	3.17	.315	100.2	625.7	525.5	.215	.027	.242	78
79	52.6	3.14	.318	100.8	625.8	525.0	.216	.025	.241	79
80	53.1	3.11	0.322	101.5	625.9	524.4	0.217	1.023	1.240	80

TABLE 3.—Saturated Ammonia: Gage Pressure Table—Continued.

Pressure (gage). lbs./in. <sup>2</sup>	Temp. °F.	Volume vapor. ft. <sup>3</sup> /lb.	Density vapor. lbs./ft. <sup>3</sup>	Heat content.		Latent heat. Btu./lb.	Entropy.			Pressure (gage). lbs./in. <sup>2</sup>
				Liquid. Btu./lb.	Vapor. Btu./lb.		Liquid. Btu./lb.°F.	Evap. Btu./lb.°F.	Vapor. Btu./lb.°F.	
<i>g. p.</i>	<i>t</i>	<i>V</i>	<i>1/V</i>	<i>h</i>	<i>H</i>	<i>L</i>	<i>s</i>	<i>L/T</i>	<i>S</i>	<i>g. p.</i>
80	53.1	3.11	0.322	101.5	625.9	524.4	0.217	1.023	1.240	80
81	53.7	3.08	.325	102.1	626.0	523.9	.219	.020	.239	81
82	54.3	3.05	.328	102.7	626.1	523.4	.220	.018	.238	82
83	54.8	3.02	.331	103.3	626.3	523.0	.221	.016	.237	83
84	55.3	2.99	.335	103.9	626.4	522.5	.222	.015	.237	84
85	55.9	2.96	0.338	104.5	626.5	522.0	0.223	1.013	1.236	85
86	56.4	2.94	.341	105.1	626.6	521.5	.224	.011	.235	86
87	57.0	2.91	.344	105.7	626.7	521.0	.226	.008	.234	87
88	57.5	2.88	.348	106.3	626.8	520.5	.227	.006	.233	88
89	58.0	2.85	.351	106.9	626.9	520.0	.228	.005	.233	89
90	58.5	2.82	0.354	107.5	627.0	519.5	0.229	1.003	1.232	90
91	59.0	2.80	.357	108.1	627.1	519.0	.230	1.001	.231	91
92	59.6	2.77	.361	108.7	627.2	518.5	.231	0.999	.230	92
93	60.1	2.75	.364	109.3	627.3	518.0	.232	.997	.229	93
94	60.6	2.72	.367	109.8	627.4	517.6	.233	.995	.228	94
95	61.1	2.70	0.370	110.4	627.5	517.1	0.235	0.993	1.228	95
96	61.6	2.68	.374	111.0	627.6	516.6	.236	.991	.227	96
97	62.0	2.65	.377	111.6	627.7	516.1	.237	.989	.226	97
98	62.5	2.63	.380	112.1	627.8	515.7	.238	.988	.226	98
99	63.0	2.61	.383	112.6	627.9	515.3	.239	.986	.225	99
100	63.5	2.59	0.287	113.2	628.0	514.8	0.240	0.984	1.224	100
102	64.5	2.54	.393	114.2	628.1	513.9	.242	.981	.223	102
104	65.4	2.50	.400	115.3	628.3	513.0	.244	.977	.221	104
106	66.4	2.46	.406	116.4	628.5	512.1	.246	.974	.220	106
108	67.3	2.42	.413	117.4	628.6	511.2	.248	.970	.218	108
110	68.2	2.39	0.419	118.5	628.8	510.3	0.250	0.967	1.217	110
112	69.1	2.35	.426	119.5	628.9	509.4	.252	.964	.216	112
114	70.0	2.31	.432	120.5	629.1	508.6	.254	.960	.214	114
116	70.8	2.28	.439	121.5	629.3	507.8	.256	.957	.213	116
118	71.7	2.25	.445	122.5	629.4	506.9	.257	.954	.211	118
120	72.6	2.21	0.452	123.5	629.5	506.0	0.259	0.951	1.210	120
122	73.4	2.18	.458	124.5	629.7	505.2	.261	.948	.209	122
124	74.2	2.15	.465	125.4	629.8	504.4	.263	.945	.208	124
126	75.1	2.12	.471	126.3	629.9	503.6	.264	.942	.206	126
128	75.9	2.09	.478	127.3	630.1	502.8	.266	.939	.205	128
130	76.7	2.06	0.484	128.2	630.2	502.0	0.268	0.936	1.204	130
132	77.5	2.04	.491	129.1	630.3	501.2	.270	.933	.203	132
134	78.3	2.01	.497	130.0	630.4	500.4	.271	.930	.201	134
136	79.1	1.98	.504	130.9	630.5	499.6	.273	.927	.200	136
138	79.9	1.96	.510	131.8	630.7	498.9	.274	.925	.199	138
140	80.6	1.93	0.517	132.7	630.8	498.1	0.276	0.922	1.198	140
142	81.4	1.91	.523	133.6	630.9	497.3	.278	.919	.197	142
144	82.2	1.89	.530	134.5	631.0	496.5	.279	.917	.196	144
146	82.9	1.86	.536	135.3	631.1	495.8	.281	.914	.195	146
148	83.6	1.84	.543	136.2	631.2	495.0	.283	.911	.194	148
150	84.4	1.82	0.550	137.0	631.3	494.3	0.284	0.909	1.193	150

TABLE 3.—Saturated Ammonia: Gage Pressure Table—Continued.

Pressure (gage). lbs./in. <sup>2</sup> <i>g. p.</i>	Temp. °F. <i>t</i>	Volume vapor. ft. <sup>3</sup> /lb. <i>V</i>	Density vapor. lbs./ft. <sup>3</sup> <i>1/V</i>	Heat content.		Latent heat. Btu./lb. <i>L</i>	Entropy.			Pressure (gage). lbs./in. <sup>2</sup> <i>g. p.</i>
				Liquid. Btu./lb. <i>h</i>	Vapor. Btu./lb. <i>H</i>		Liquid Btu./lb. °F. <i>s</i>	Evap. Btu./lb. °F. <i>L/T</i>	Vapor. Btu./lb. °F. <i>S</i>	
150	84.4	1.82	0.550	137.0	631.3	494.3	0.284	0.909	1.193	150
152	85.1	1.80	.566	137.9	631.4	493.5	.286	.906	.192	152
154	85.8	1.78	.563	138.7	631.5	492.8	.287	.904	.191	154
156	86.5	1.76	.569	139.5	631.6	492.1	.289	.901	.190	156
158	87.2	1.74	.576	140.3	631.7	491.4	.290	.899	.189	158
160	88.0	1.72	0.582	141.1	631.8	490.7	0.292	0.896	1.188	160
162	88.6	1.70	.589	141.9	631.9	490.0	.293	.894	.187	162
164	89.3	1.68	.595	142.7	631.9	489.2	.294	.891	.185	164
166	90.0	1.66	.602	143.5	632.0	488.5	.296	.889	.185	166
168	90.7	1.64	.609	144.3	632.1	487.8	.297	.886	.183	168
170	91.4	1.62	0.615	145.1	632.1	487.0	0.299	0.884	1.183	170
172	92.0	1.61	.622	145.8	632.2	486.4	.300	.882	.182	172
174	92.7	1.59	.628	146.6	632.3	485.7	.302	.879	.181	174
176	93.4	1.57	.635	147.4	632.4	485.0	.303	.877	.180	176
178	94.0	1.56	.641	148.2	632.5	484.3	.304	.875	.179	178
180	94.7	1.54	0.648	148.9	632.5	483.6	0.305	0.873	1.178	180
182	95.3	1.53	.655	149.7	632.6	482.9	.307	.870	.177	182
184	95.9	1.51	.661	150.5	632.7	482.2	.308	.868	.176	184
186	96.6	1.50	.668	151.2	632.7	481.5	.309	.866	.175	186
188	97.2	1.48	.674	151.9	632.8	480.9	.311	.863	.174	188
190	97.8	1.47	0.681	152.6	632.8	480.2	0.312	0.861	1.173	190
192	98.4	1.45	.688	153.4	632.9	479.5	.314	.859	.173	192
194	99.0	1.44	.694	154.0	632.9	478.9	.315	.857	.172	194
196	99.7	1.43	.701	154.8	633.0	478.2	.316	.855	.171	196
198	100.3	1.41	.708	155.5	633.0	477.5	.317	.853	.170	198
200	100.9	1.40	0.714	156.2	633.1	476.9	0.318	0.851	1.169	200
205	102.3	1.37	.731	158.0	633.2	475.2	.321	.846	.167	205
210	103.8	1.34	.747	159.6	633.3	473.7	.324	.841	.165	210
215	105.2	1.31	.764	161.3	633.4	472.1	.327	.836	.163	215
220	106.6	1.28	.781	163.0	633.5	470.5	.330	.831	.161	220
225	108.0	1.25	0.797	164.6	633.6	469.0	0.333	0.826	1.159	225
230	109.4	1.23	.814	166.3	633.7	467.4	.336	.822	.158	230
235	110.7	1.20	.831	167.9	633.8	465.9	.339	.817	.156	235
240	112.0	1.18	.848	169.4	633.8	464.4	.341	.813	.154	240
245	113.3	1.16	.864	171.0	633.9	462.9	.344	.808	.152	245
250	114.6	1.13	0.881	172.6	633.9	461.3	0.346	0.804	1.150	250
255	115.9	1.11	.898	174.1	634.0	459.9	.349	.799	.148	255
260	117.1	1.09	.915	175.6	634.0	458.4	.352	.795	.147	260
265	118.4	1.07	.932	177.0	634.0	457.0	.354	.791	.145	265
270	119.6	1.05	.949	178.5	634.0	455.5	.357	.786	.143	270
275	120.8	1.03	0.966	179.9	634.0	454.1	0.359	0.783	1.142	275
280	122.0	1.02	.983	181.4	634.0	452.6	.362	.778	.140	280
285	123.1	1.00	1.000	182.8	634.0	451.2	.364	.774	.138	285
290	124.3	0.98	1.018	184.2	634.0	449.8	.367	.770	.137	290
295	125.4	0.97	1.035	185.6	634.0	448.4	.369	.766	.135	295
300	126.5	0.95	1.052	187.0	633.9	446.9	0.371	0.762	1.133	300

TABLE 4.—Properties of Liquid Ammonia.

Temp. °F.	Saturation.						Latent heat of pressure variation. Btu./lb. lb./in. <sup>2</sup>	Variation of $h$ with $p$ ( $t$ con- stant). Btu./lb. lb./in. <sup>2</sup>	Com- press- ibility. per lb./in. <sup>2</sup> × 10 <sup>4</sup>	Temp. °F.
	Pressure (abs.). lbs./in. <sup>2</sup>	Volume. ft. <sup>3</sup> /lb.	Density. lbs./ft. <sup>3</sup>	Specific heat. Btu./lb. °F.	Heat content. Btu./lb.	Latent heat. Btu./lb.				
$t$	$p$	$v$	$\frac{1}{v}$	$c$	$h$	$L$	$l$	$\left(\frac{\partial h}{\partial p}\right)_t$	$\frac{1}{v} \left(\frac{\partial v}{\partial p}\right)_t$	$t$
Triple point.	0.88	0.01961*	51.00*	.....	.....	.....	.....	.....	.....	-107.86
-100	1.24	0.02197	45.52	(1.040)	(-63.0)	(633)	.....	.....	.....	-100
-95	1.52	0.02207	45.32	(1.042)	(-57.8)	(631)	.....	.....	.....	-95
-90	1.86	0.02216	45.12	(1.043)	(-52.6)	(628)	.....	.....	.....	-90
-85	2.27	0.02226	44.92	(1.045)	(-47.4)	(625)	.....	.....	.....	-85
-80	2.74	0.02236	44.72	(1.046)	(-42.2)	(622)	.....	.....	.....	-80
-75	3.29	0.02246	44.52	(1.048)	(-36.9)	(619)	.....	.....	.....	-75
-70	3.94	0.02256	44.32	(1.050)	(-31.7)	(616)	.....	.....	.....	-70
-65	4.69	0.02267	44.11	(1.052)	(-26.4)	(613)	.....	.....	.....	-65
-60	5.55	0.02278	43.91	1.054	-21.18	610.8	-0.0016	0.0026	4.4	-60
-55	6.54	0.02288	43.70	1.056	-15.90	607.5	-0.0016	0.0026	4.5	-55
-50	7.67	0.02299	43.49	1.058	-10.61	604.3	-0.0017	0.0026	4.6	-50
-45	8.95	0.02310	43.28	1.060	-5.31	600.9	-0.0017	0.0026	4.7	-45
-40	10.41	0.02322	43.08	1.062	0.00	597.6	-0.0018	0.0025	4.8	-40
-35	12.05	0.02333	42.86	1.064	+5.32	594.2	-0.0018	0.0025	5.0	-35
-30	13.90	0.02345	42.65	1.066	10.66	590.7	-0.0019	0.0025	5.1	-30
-25	15.98	0.02357	42.44	1.068	16.00	587.2	-0.0019	0.0024	5.2	-25
-20	18.30	0.02369	42.22	1.070	21.36	583.6	-0.0020	0.0024	5.4	-20
-15	20.88	0.02381	42.00	1.073	26.73	580.0	-0.0020	0.0024	5.5	-15
-10	23.74	0.02393	41.78	1.075	32.11	576.4	-0.0021	0.0023	5.7	-10
-5	26.92	0.02406	41.56	1.078	37.51	572.6	-0.0022	0.0023	5.8	-5
0	30.42	0.02419	41.34	1.080	42.92	568.9	-0.0022	0.0022	6.0	0
5	34.27	0.02432	41.11	1.083	48.35	565.0	-0.0023	0.0022	6.2	5
10	38.51	0.02446	40.89	1.085	53.79	561.1	-0.0024	0.0021	6.4	10
15	43.14	0.02460	40.66	1.088	59.24	557.1	-0.0025	0.0021	6.6	15
20	48.21	0.02474	40.43	1.091	64.71	553.1	-0.0025	0.0020	6.8	20
25	53.73	0.02488	40.20	1.094	70.20	548.9	-0.0026	0.0020	7.0	25
30	59.74	0.02503	39.96	1.097	75.71	544.8	-0.0027	0.0019	7.3	30
35	66.26	0.02518	39.72	1.100	81.23	540.5	-0.0028	0.0019	7.5	35
40	73.32	0.02533	39.49	1.104	86.77	536.2	-0.0029	0.0018	7.8	40
45	80.96	0.02548	39.24	1.108	92.34	531.8	-0.0030	0.0017	8.1	45
50	89.19	0.02564	39.00	1.112	97.93	527.3	-0.0031	0.0017	8.4	50
55	98.06	0.02581	38.75	1.116	103.54	522.8	-0.0032	0.0016	8.8	55
60	107.6	0.02597	38.50	1.120	109.18	518.1	-0.0033	0.0015	9.1	60
65	117.8	0.02614	38.25	1.125	114.85	513.4	-0.0034	0.0014	9.5	65
70	128.8	0.02632	38.00	1.129	120.54	508.6	-0.0035	0.0013	10.0	70
75	140.5	0.02650	37.74	1.133	126.25	503.7	-0.0037	0.0012	10.4	75

\*Properties of solid ammonia at the triple point (-107.86 °F.)

TABLE 4.—Properties of Liquid Ammonia—Continued.

Temp. °F.	Saturation.						Latent heat of pressure variation. Btu./lb. lb./in. <sup>2</sup>	Variation of $h$ with $p$ ( $t$ con- stant). Btu./lb. lb./in. <sup>2</sup>	Com- press- ibility. per lb./in. <sup>2</sup> × 10 <sup>3</sup> $-\frac{1}{v} \left( \frac{\partial v}{\partial p} \right)_t$	Temp. °F.
	Pressure (abs.). lbs./in. <sup>2</sup>	Volume. ft. <sup>3</sup> /lb.	Density. lbs./ft. <sup>3</sup>	Specific heat. Btu./lb. °F.	Heat content. Btu./lb.	Latent heat. Btu./lb.				
$t$	$p$	$v$	$\frac{1}{v}$	$c$	$h$	$L$	$l$	$\left( \frac{\partial h}{\partial p} \right)_t$	$-\frac{1}{v} \left( \frac{\partial v}{\partial p} \right)_t$	$t$
75	140.5	0.02650	37.74	1.133	126.25	503.7	-0.0037	0.0012	10.4	75
80	153.0	.02668	37.48	1.138	131.99	498.7	- .0038	.0011	10.9	80
85	166.4	.02687	37.21	1.142	137.75	493.6	- .0040	.0010	11.4	85
90	180.6	.02707	36.95	1.147	143.54	488.5	- .0041	.0009	12.0	90
95	195.8	.02727	36.67	1.151	149.36	483.2	- .0043	.0008	12.6	95
100	211.9	0.02747	36.40	1.156	155.21	477.8	-0.0045	0.0006	13.3	100
105	228.9	.02769	36.12	1.162	161.09	472.3	- .0047	.0005	14.1	105
110	247.0	.02790	35.84	1.168	167.01	466.7	- .0049	.0003	14.9	110
115	266.2	.02813	35.55	1.176	172.97	460.9	- .0051	.0001	15.8	115
120	286.4	.02836	35.26	1.183	178.98	455.0	- .0053	.0000	16.7	120
125	307.8	0.02860	34.96	(1.189)	(185)	(449)	.....	.....	.....	125
130	330.3	.02885	34.66	(1.197)	(191)	(443)	.....	.....	.....	130
135	354.1	.02911	34.35	(1.205)	(197)	(436)	.....	.....	.....	135
140	379.1	.02938	34.04	(1.213)	(203)	(430)	.....	.....	.....	140
145	405.5	.02966	33.72	(1.222)	(210)	(423)	.....	.....	.....	145
150	433.2	0.02995	33.39	(1.23 )	(216)	(416)	.....	.....	.....	150
155	462.3	.03025	33.06	(1.24 )	(222)	(409)	.....	.....	.....	155
160	492.8	.03056	32.72	(1.25 )	(229)	(401)	.....	.....	.....	160
165	524.8	.03089	32.37	(1.26 )	(235)	(394)	.....	.....	.....	165
170	558.4	.03124	32.01	(1.27 )	(241)	(386)	.....	.....	.....	170
175	593.5	0.03160	31.65	(1.29 )	(248)	(377)	.....	.....	.....	175
180	630.3	.03198	31.27	(1.30 )	(255)	(369)	.....	.....	.....	180
185	668.7	.03238	30.88	(1.32 )	(262)	(360)	.....	.....	.....	185
190	708.9	.03281	30.48	(1.34 )	(269)	(351)	.....	.....	.....	190
195	750.9	.03326	30.06	(1.36 )	(276)	(342)	.....	.....	.....	195
200	794.7	0.03375	29.63	(1.38 )	(283)	(332)	.....	.....	.....	200
210	888.1	.03482	28.72	(1.43 )	(297)	(310)	.....	.....	.....	210
220	989.5	.0361	27.7	(1.49 )	(313)	(287)	.....	.....	.....	220
230	1099.5	.0376	26.6	(1.57 )	(329)	(260)	.....	.....	.....	230
240	1218.5	.0395	25.3	(1.70 )	(346)	(229)	.....	.....	.....	240
250	1347	.0422	23.7	(1.90 )	(365)	(192)	.....	.....	.....	250
260	1486	.0463	21.6	(2.33 )	(387)	(142)	.....	.....	.....	260
270	1635	.0577	17.3	(5.30 )	(419)	(52)	.....	.....	.....	270
Critical.	1657	.0686	14.6	∞	(433)	0	- ∞	- ∞	∞	271.4

NOTE.—The figures in parentheses were calculated from empirical equations given in Bureau of Standards Scientific Papers Nos. 313 and 315 and represent values obtained by extrapolation beyond the range covered in the experimental work.

**TABLE 5.—Properties of Superheated Ammonia Vapor.**  
V=volume in ft.<sup>3</sup>/lb.; H=heat content in Btu./lb.; S=entropy in Btu./lb. °F.

Temp. °F.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)									Temp. °F.
	5 -63.11°			6 -57.64°			7 -52.88°			
	V	H	S	V	H	S	V	H	S	
<i>Sat.</i>	<i>49.81</i>	<i>588.5</i>	<i>1.4867</i>	<i>41.69</i>	<i>590.8</i>	<i>1.4708</i>	<i>36.01</i>	<i>592.5</i>	<i>1.4574</i>	<i>Sat.</i>
-50	51.06	595.2	1.5025	42.44	594.6	1.4803	36.29	594.0	1.4611	-50
-40	52.36	600.3	.5149	43.55	599.8	.4928	37.25	599.3	.4739	-40
-30	53.67	605.4	.5269	44.64	604.9	.5049	38.19	604.5	.4861	-30
-20	54.97	610.4	.5385	45.73	610.0	.5166	39.13	609.6	.4979	-20
-10	56.26	615.4	.5498	46.82	615.1	.5280	40.07	614.7	.5094	-10
0	57.55	620.4	1.5608	47.90	620.1	1.5391	41.00	619.8	1.5206	0
10	58.84	625.4	.5716	48.98	625.2	.5499	41.93	624.9	.5314	10
20	60.12	630.4	.5821	50.05	630.2	.5605	42.85	629.9	.5421	20
30	61.41	635.4	.5925	51.12	635.2	.5708	43.77	635.0	.5525	30
40	62.69	640.4	.6026	52.19	640.2	.5810	44.69	640.0	.5627	40
50	63.96	645.5	1.6125	53.26	645.2	1.5910	45.61	645.0	1.5727	50
60	65.24	650.5	.6223	54.32	650.3	.6008	46.53	650.1	.5825	60
70	66.51	655.5	.6319	55.39	655.3	.6104	47.44	655.2	.5921	70
80	67.79	660.6	.6413	56.45	660.4	.6199	48.36	660.2	.6016	80
90	69.06	665.6	.6506	57.51	665.5	.6292	49.27	665.3	.6110	90
100	70.33	670.7	1.6598	58.58	670.6	1.6384	50.18	670.4	1.6202	100
110	71.60	675.8	.6689	59.64	675.7	.6474	51.09	675.5	.6292	110
120	72.87	680.9	.6778	60.70	680.8	.6563	52.00	680.7	.6382	120
130	74.14	686.1	.6865	61.76	685.9	.6651	52.91	685.8	.6470	130
140	75.41	691.2	.6952	62.82	691.1	.6738	53.82	691.0	.6557	140
150	76.68	696.4	1.7038	63.87	696.3	1.6824	54.73	696.2	1.6643	150
160	77.95	701.6	.7122	64.93	701.5	.6909	55.63	701.4	.6727	160
170	79.21	706.8	.7206	65.99	706.7	.6992	56.54	706.6	.6811	170
180	80.48	712.1	.7289	67.05	712.0	.7075	57.45	711.9	.6894	180
	10 -41.34°			11 -38.14°			12 -35.16°			
<i>Sat.</i>	<i>25.81</i>	<i>597.1</i>	<i>1.4876</i>	<i>23.61</i>	<i>598.3</i>	<i>1.4198</i>	<i>21.77</i>	<i>599.4</i>	<i>1.4124</i>	<i>Sat.</i>
-30	26.58	603.2	1.4420	24.12	602.7	1.4300	22.07	602.3	1.4190	-30
-20	27.26	608.5	.4542	24.74	608.1	.4423	22.64	607.7	.4314	-20
-10	27.92	613.7	.4659	25.35	613.3	.4542	23.20	613.0	.4434	-10
0	28.58	618.9	1.4773	25.95	618.5	1.4656	23.75	618.2	1.4549	0
10	29.24	624.0	.4884	26.55	623.7	.4768	24.31	623.4	.4661	10
20	29.90	629.1	.4992	27.15	628.9	.4876	24.86	628.6	.4770	20
30	30.55	634.2	.5097	27.74	634.0	.4982	25.41	633.7	.4877	30
40	31.20	639.3	.5200	28.34	639.1	.5085	25.95	638.9	.4980	40
50	31.85	644.4	1.5301	28.93	644.2	1.5187	26.49	644.0	1.5082	50
60	32.49	649.5	.5400	29.52	649.3	.5286	27.03	649.1	.5182	60
70	33.14	654.6	.5497	30.10	654.4	.5383	27.57	654.3	.5279	70
80	33.78	659.7	.5593	30.69	659.6	.5479	28.11	659.4	.5375	80
90	34.42	664.8	.5687	31.28	664.7	.5573	28.65	664.5	.5470	90
100	35.07	670.0	1.5779	31.86	669.8	1.5666	29.19	669.7	1.5562	100
110	35.71	675.1	.5870	32.44	675.0	.5757	29.72	674.8	.5654	110
120	36.35	680.3	.5960	33.03	680.1	.5847	30.26	680.0	.5744	120
130	36.99	685.4	.6049	33.61	685.3	.5936	30.79	685.2	.5833	130
140	37.62	690.6	.6136	34.19	690.5	.6023	31.33	690.4	.5920	140
150	38.26	695.8	1.6222	34.77	695.7	1.6109	31.86	695.6	1.6006	150
160	38.90	701.1	.6307	35.35	700.9	.6194	32.39	700.8	.6092	160
170	39.54	706.3	.6391	35.93	706.2	.6278	32.92	706.1	.6176	170
180	40.17	711.6	.6474	36.51	711.5	.6362	33.46	711.4	.6259	180
190	40.81	716.9	.6556	37.09	716.8	.6444	33.99	716.7	.6341	190
200	41.45	722.2	1.6637	37.67	722.1	1.6525	34.52	722.0	1.6422	200

**TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.**

[V—volume in ft.<sup>3</sup>/lb.; H—heat content in Btu./lb.; S—entropy in Btu./lb. °F.]

Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)										
Temp. °F.	8 —48.64°			9 —44.38°			10 —41.34°			Temp. °F.
	V	H	S	V	H	S	V	H	S	
	Sat.	31.79	594.2	1.4462	28.48	595.7	1.4363	25.81	597.1	
—50	32.52	598.8	1.4573	28.85	598.3	1.4426	25.90	597.8	1.4293	—50
—40	33.36	604.1	.4697	29.59	603.6	.4551	26.58	603.2	.4420	—40
—30	34.19	609.3	.4816	30.34	608.9	.4672	27.26	608.5	.4542	—30
—20	35.01	614.4	.4932	31.07	614.0	.4788	27.92	613.7	.4659	—20
—10	35.83	619.5	1.5044	31.80	619.2	1.4902	28.58	618.9	1.4773	—10
0	36.64	624.6	.5154	32.53	624.3	.5012	29.24	624.0	.4884	0
10	37.45	629.7	.5261	33.26	629.4	.5119	29.90	629.1	.4992	10
20	38.26	634.7	.5365	33.98	634.5	.5224	30.55	634.2	.5097	20
30	39.07	639.8	.5467	34.70	639.5	.5327	31.20	639.3	.5200	30
40	39.88	644.8	1.5568	35.42	644.6	1.5427	31.85	644.4	1.5301	40
50	40.68	649.9	.5666	36.13	649.7	.5526	32.49	649.5	.5400	50
60	41.48	655.0	.5763	36.85	654.8	.5623	33.14	654.6	.5497	60
70	42.28	660.1	.5858	37.56	659.9	.5718	33.78	659.7	.5593	70
80	43.08	665.2	.5952	38.27	665.0	.5812	34.42	664.8	.5687	80
90	43.88	670.3	1.6044	38.98	670.1	1.5904	35.07	670.0	1.5779	90
100	44.68	675.4	.6135	39.70	675.3	.5995	35.71	675.1	.5870	100
110	45.48	680.5	.6224	40.40	680.4	.6085	36.35	680.3	.5960	110
120	46.27	685.7	.6312	41.11	685.6	.6173	36.99	685.4	.6049	120
130	47.07	690.9	.6399	41.82	690.7	.6260	37.62	690.6	.6136	130
140	47.87	696.1	1.6485	42.53	695.9	1.6346	38.26	695.8	1.6222	140
150	48.66	701.3	.6570	43.24	701.2	.6431	38.90	701.1	.6307	150
160	49.46	706.5	.6654	43.95	706.4	.6515	39.54	706.3	.6391	160
170	50.25	711.8	.6737	44.65	711.7	.6598	40.17	711.6	.6474	170
180										180
13 —32.37°										
Sat.	20.20	600.5	1.4057	18.85	601.4	1.3998	17.67	602.4	1.3938	Sat.
—30	20.33	601.8	1.4088	19.33	606.8	1.4119	18.01	606.4	1.4031	—30
—20	20.86	607.2	.4213	19.33	606.8	1.4119	18.01	606.4	1.4031	—20
—10	21.38	612.6	.4334	19.82	612.2	.4241	18.47	611.9	.4154	—10
0	21.90	617.9	1.4450	20.30	617.6	1.4358	18.92	617.2	1.4272	0
10	22.41	623.1	.4563	20.78	622.8	.4472	19.37	622.5	.4386	10
20	22.92	628.3	.4672	21.26	628.0	.4582	19.82	627.8	.4497	20
30	23.43	633.5	.4779	21.73	633.2	.4688	20.26	633.0	.4604	30
40	23.93	638.6	.4883	22.20	638.4	.4793	20.70	638.2	.4709	40
50	24.43	643.8	1.4985	22.67	643.6	1.4896	21.14	643.4	1.4812	50
60	24.94	648.9	.5085	23.14	648.7	.4996	21.58	648.5	.4912	60
70	25.43	654.1	.5183	23.60	653.9	.5094	22.01	653.7	.5011	70
80	25.93	659.2	.5279	24.06	659.0	.5191	22.44	658.9	.5108	80
90	26.43	664.4	.5374	24.53	664.2	.5285	22.88	664.0	.5203	90
100	26.93	669.5	1.5467	24.99	669.4	1.5378	23.31	669.2	1.5296	100
110	27.42	674.7	.5558	25.45	674.5	.5470	23.74	674.4	.5388	110
120	27.92	679.9	.5649	25.91	679.7	.5560	24.17	679.6	.5478	120
130	28.41	685.1	.5737	26.37	684.9	.5649	24.60	684.8	.5567	130
140	28.90	690.3	.5825	26.83	690.1	.5737	25.03	690.0	.5655	140
150	29.40	695.5	1.5911	27.29	695.4	1.5824	25.46	695.3	1.5742	150
160	29.89	700.7	.5997	27.74	700.6	.5909	25.88	700.5	.5827	160
170	30.38	706.0	.6081	28.20	705.9	.5993	26.31	705.8	.5911	170
180	30.87	711.3	.6164	28.66	711.2	.6076	26.74	711.1	.5995	180
190	31.36	716.6	.6246	29.11	716.5	.6159	27.16	716.4	.6077	190
200	31.85	721.9	1.6328	29.57	721.8	1.6240	27.59	721.7	1.6158	200

TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.

[V=volume in ft.<sup>3</sup>/lb.; H=heat content in Btu./lb.; S=entropy in Btu./lb. °F.]

Temp. °F.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)									Temp. °F.
	15 -27.29°			16 -24.26°			17 -22.75°			
	V	H	S	V	H	S	V	H	S	
<i>Sat.</i>	17.67	606.4	1.5938	16.64	606.3	1.5885	15.78	604.0	1.5835	<i>Sat.</i>
-20	18.01	606.4	1.4031	16.86	606.0	1.3948	15.83	605.6	1.3870	-20
-10	18.47	611.9	.4154	17.29	611.5	.4072	16.24	611.1	.3994	-10
0	18.92	617.2	1.4272	17.72	616.9	1.4191	16.65	616.6	1.4114	0
10	19.37	622.5	.4386	18.14	622.2	.4306	17.05	621.9	.4230	10
20	19.82	627.8	.4497	18.56	627.5	.4417	17.45	627.2	.4342	20
30	20.26	633.0	.4604	18.97	632.7	.4525	17.84	632.5	.4450	30
40	20.70	638.2	.4709	19.39	638.0	.4630	18.23	637.7	.4556	40
50	21.14	643.4	1.4812	19.80	643.2	1.4733	18.62	642.9	1.4659	50
60	21.58	648.5	.4912	20.21	648.3	.4834	19.01	648.1	.4761	60
70	22.01	653.7	.5011	20.62	653.5	.4933	19.39	653.3	.4860	70
80	22.44	658.9	.5108	21.03	658.7	.5030	19.78	658.5	.4957	80
90	22.88	664.0	.5203	21.43	663.9	.5125	20.16	663.7	.5052	90
100	23.31	669.2	1.5296	21.84	669.1	1.5218	20.54	668.9	1.5146	100
110	23.74	674.4	.5388	22.24	674.3	.5310	20.92	674.1	.5238	110
120	24.17	679.6	.5478	22.65	679.5	.5401	21.30	679.3	.5328	120
130	24.60	684.8	.5567	23.05	684.7	.5490	21.68	684.5	.5418	130
140	25.03	690.0	.5655	23.45	689.9	.5578	22.06	689.8	.5506	140
150	25.46	695.3	1.5742	23.86	695.1	1.5665	22.44	695.0	1.5593	150
160	25.88	700.5	.5827	24.26	700.4	.5750	22.82	700.3	.5678	160
170	26.31	705.8	.5911	24.66	705.7	.5835	23.20	705.6	.5763	170
180	26.74	711.1	.5995	25.06	711.0	.5918	23.58	710.9	.5846	180
190	27.16	716.4	.6077	25.46	716.3	.6001	23.95	716.2	.5929	190
200	27.59	721.7	1.6158	25.86	721.6	1.6082	24.33	721.5	1.6010	200
220	28.44	732.4	.6318	26.66	732.3	.6242	25.08	732.2	.6170	220
	20 -16.64°			21 -14.78°			22 -12.98°			
<i>Sat.</i>	13.50	606.3	1.5700	12.90	606.8	1.5659	12.35	607.4	1.5631	<i>Sat.</i>
-10	13.74	610.0	1.3784	13.06	609.6	1.3720	12.45	609.2	1.3659	-10
0	14.09	615.5	1.3907	13.40	615.2	1.3844	12.77	614.8	1.3784	0
10	14.44	621.0	.4025	13.73	620.7	.3962	13.09	620.4	.3903	10
20	14.78	626.4	.4138	14.06	626.1	.4077	13.40	625.8	.4018	20
30	15.11	631.7	.4248	14.38	631.5	.4187	13.71	631.2	.4129	30
40	15.45	637.0	.4356	14.70	636.8	.4295	14.02	636.6	.4237	40
50	15.78	642.3	1.4460	15.02	642.1	1.4400	14.32	641.9	1.4342	50
60	16.12	647.5	.4562	15.34	647.3	.4502	14.63	647.1	.4445	60
70	16.45	652.8	.4662	15.65	652.6	.4602	14.93	652.4	.4545	70
80	16.78	658.0	.4760	15.97	657.8	.4700	15.23	657.7	.4643	80
90	17.10	663.2	.4856	16.28	663.1	.4796	15.53	662.9	.4740	90
100	17.43	668.5	1.4650	16.59	668.3	1.4891	15.83	668.1	1.4834	100
110	17.76	673.7	.5042	16.90	673.5	.4983	16.12	673.4	.4927	110
120	18.08	678.9	.5133	17.21	678.8	.5075	16.42	678.6	.5019	120
130	18.41	684.2	.5223	17.52	684.0	.5165	16.72	683.9	.5109	130
140	18.73	689.4	.5312	17.83	689.3	.5253	17.01	689.2	.5197	140
150	19.05	694.7	1.5399	18.14	694.6	1.5340	17.31	694.4	1.5285	150
160	19.37	700.0	.5485	18.44	699.8	.5426	17.60	699.7	.5371	160
170	19.70	705.3	.5569	18.75	705.1	.5510	17.89	705.0	.5456	170
180	20.02	710.6	.5653	19.06	710.5	.5595	18.19	710.4	.5539	180
190	20.34	715.9	.5736	19.36	715.8	.5678	18.48	715.7	.5622	190
200	20.66	721.2	1.5817	19.67	721.1	1.5759	18.77	721.1	1.5704	200
220	21.30	732.0	.5978	20.28	731.9	.5920	19.35	731.8	.5865	220
240	21.94	742.8	.6135	20.89	742.7	.6077	19.94	742.7	.6022	240

TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.

[V=volume in ft.<sup>3</sup>/lb.; H=heat content in Btu./lb.; S=entropy in Btu./lb. °F.]

Temp. °F.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)									Temp. °F.
	18 -20.61°			19 -18.58°			20 -16.64°			
	V	H	S	V	H	S	V	H	S	
Sat.	14.90	604.8	1.5787	14.17	606.5	1.5748	13.60	606.8	1.5700	Sat.
-20	14.93	605.1	1.3795	14.49	610.3	1.3851	13.74	610.0	1.3784	-20
-10	15.32	610.7	.3921	14.85	615.9	1.3973	14.09	615.5	1.3907	-10
0	15.70	616.2	1.4042	15.21	621.3	.4090	14.44	621.0	.4025	0
10	16.08	621.6	.4158	15.57	626.7	.4203	14.78	626.4	.4138	10
20	16.46	626.9	.4270	15.93	632.0	.4312	15.11	631.7	.4248	20
30	16.83	632.2	.4380	16.28	637.3	.4419	15.45	637.0	.4356	30
40	17.20	637.5	.4486	16.63	642.5	1.4523	15.78	642.3	1.4460	40
50	17.57	642.7	1.4590	16.98	647.7	.4625	16.12	647.5	.4562	50
60	17.94	647.9	.4691	17.33	653.0	.4724	16.45	652.8	.4662	60
70	18.30	653.1	.4790	17.67	658.2	.4822	16.78	658.0	.4760	70
80	18.67	658.4	.4887	18.02	663.4	.4918	17.10	663.2	.4856	80
90	19.03	663.6	.4983	18.36	668.6	1.5012	17.43	668.5	1.4950	90
100	19.39	668.8	1.5077	18.70	673.8	.5104	17.76	673.7	.5042	100
110	19.75	674.0	.5169	19.04	679.1	.5195	18.08	678.9	.5133	110
120	20.11	679.2	.5260	19.38	684.3	.5285	18.41	684.2	.5223	120
130	20.47	684.4	.5349	19.72	689.5	.5373	18.73	689.4	.5312	130
140	20.83	689.7	.5438	20.06	694.8	1.5460	19.05	694.7	1.5399	140
150	21.19	694.9	1.5525	20.40	700.1	.5546	19.37	700.0	.5485	150
160	21.54	700.2	.5610	20.74	705.4	.5631	19.70	705.3	.5569	160
170	21.90	705.5	.5695	21.08	710.7	.5714	20.02	710.6	.5653	170
180	22.26	710.8	.5778	21.42	716.0	.5797	20.34	715.9	.5736	180
190	22.61	716.1	.5861	21.75	721.3	1.5878	20.66	721.2	1.5817	190
200	22.97	721.4	1.5943	22.43	732.1	.6039	21.30	732.0	.5978	200
220	23.68	732.2	.6103							220
	23 -11.85°			24 -9.58°			25 -7.96°			
Sat.	11.86	608.1	1.5684	11.59	608.8	1.5649	10.96	609.1	1.5616	Sat.
-10	11.89	608.8	1.3600	11.67	614.1	1.3670	11.19	613.8	1.3616	-10
0	12.20	614.5	1.3726	11.96	619.7	.3791	11.47	619.4	.3738	0
10	12.50	620.0	.3846	12.25	625.2	.3907	11.75	625.0	.3855	10
20	12.80	625.5	.3961	12.54	630.7	.4019	12.03	630.4	.3967	20
30	13.10	630.9	.4073	12.82	636.1	.4128	12.30	635.8	.4077	30
40	13.40	636.3	.4181	13.11	641.4	1.4234	12.57	641.2	1.4183	40
50	13.69	641.6	1.4287	13.39	646.7	.4337	12.84	646.5	.4287	50
60	13.98	646.9	.4390	13.66	652.0	.4438	13.11	651.8	.4388	60
70	14.27	652.2	.4491	13.94	657.3	.4537	13.37	657.1	.4487	70
80	14.56	657.5	.4589	14.22	662.6	.4634	13.64	662.4	.4584	80
90	14.84	662.7	.4686	14.49	667.8	1.4729	13.90	667.7	1.4679	90
100	15.13	668.0	1.4780	14.76	673.1	.4822	14.17	673.0	.4772	100
110	15.41	673.2	.4873	15.04	678.4	.4914	14.43	678.2	.4864	110
120	15.70	678.5	.4965	15.31	683.6	.5004	14.69	683.5	.4954	120
130	15.98	683.8	.5055	15.58	688.9	.5093	14.95	688.8	.5043	130
140	16.26	689.0	.5144	15.85	694.2	1.5180	15.21	694.1	1.5131	140
150	16.55	694.3	1.5231	16.12	699.5	.5266	15.47	699.4	.5217	150
160	16.83	699.6	.5317	16.39	704.8	.5352	15.73	704.7	.5303	160
170	17.11	704.9	.5402	16.66	710.2	.5436	15.99	710.1	.5387	170
180	17.39	710.3	.5486	16.93	715.5	.5518	16.25	715.4	.5470	180
190	17.67	715.6	.5569	17.20	720.9	1.5600	16.50	720.8	1.5552	190
200	17.95	721.0	1.5651	17.73	731.7	.5761	17.02	731.6	.5713	200
220	18.51	731.7	.5812	18.27	742.6	.5919	17.53	742.5	.5870	220
240	19.07	742.6	.5969							240

TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.

[V=volume in ft.<sup>3</sup>/lb.; H=heat content in Btu./lb.; S=entropy in Btu./lb. °F.]

Temp. ° F.	Absolute pressure in lbs. / in. <sup>2</sup> (Saturation temperature in italics.)									Temp. ° F.
	25 -7.96°			26 -6.59°			27 -4.87°			
	V	H	S	V	H	S	V	H	S	
<i>Sat.</i>	<i>10.96</i>	<i>609.1</i>	<i>1.3515</i>	<i>10.56</i>	<i>609.7</i>	<i>1.3488</i>	<i>10.80</i>	<i>610.8</i>	<i>1.3451</i>	<i>Sat.</i>
0	11.19	613.8	1.3616	10.74	613.4	1.3564	10.33	613.0	1.3513	0
10	11.47	619.4	.3738	11.01	619.1	.3686	10.59	618.8	.3637	10
20	11.75	625.0	.3855	11.28	624.7	.3804	10.85	624.4	.3755	20
30	12.03	630.4	.3967	11.55	630.2	.3917	11.11	629.9	.3869	30
40	12.30	635.8	.4077	11.81	635.6	.4027	11.37	635.4	.3979	40
50	12.57	641.2	1.4183	12.08	641.0	1.4134	11.62	640.8	1.4087	50
60	12.84	646.5	.4287	12.34	646.3	.4238	11.87	646.1	.4191	60
70	13.11	651.8	.4388	12.59	651.6	.4339	12.12	651.5	.4292	70
80	13.37	657.1	.4487	12.85	656.9	.4439	12.37	656.8	.4392	80
90	13.64	662.4	.4584	13.11	662.2	.4536	12.61	662.1	.4489	90
100	13.90	667.7	1.4679	13.36	667.5	1.4631	12.86	667.4	1.4585	100
110	14.17	673.0	.4772	13.61	672.8	.4725	13.10	672.7	.4679	110
120	14.43	678.2	.4864	13.87	678.1	.4817	13.34	678.0	.4771	120
130	14.69	683.5	.4954	14.12	683.4	.4907	13.59	683.3	.4861	130
140	14.95	688.8	.5043	14.37	688.7	.4996	13.83	688.6	.4950	140
150	15.21	694.1	1.5131	14.62	694.0	1.5084	14.07	693.9	1.5038	150
160	15.47	699.4	.5217	14.87	699.3	.5170	14.31	699.2	.5125	160
170	15.73	704.7	.5303	15.12	704.6	.5256	14.55	704.5	.5210	170
180	15.99	710.1	.5387	15.37	710.0	.5340	14.79	709.9	.5295	180
190	16.25	715.4	.5470	15.62	715.3	.5423	15.03	715.2	.5378	190
200	16.50	720.8	1.5552	15.86	720.7	1.5505	15.27	720.6	1.5460	200
220	17.02	731.6	.5713	16.36	731.5	.5666	15.75	731.4	.5621	220
240	17.53	742.5	.5870	16.85	742.4	.5824	16.23	742.3	.5779	240
260	18.04	753.4	.6025	17.35	753.3	.5978	16.70	753.2	.5933	260
	30 -0.57°			31 +0.79°			32 +8.11°			
<i>Sat.</i>	<i>9.296</i>	<i>611.6</i>	<i>1.3964</i>	<i>8.955</i>	<i>612.0</i>	<i>1.3898</i>	<i>8.698</i>	<i>612.4</i>	<i>1.3810</i>	<i>Sat.</i>
10	9.492	617.8	1.3497	9.173	617.4	1.3453	8.874	617.1	1.3411	10
20	9.731	623.5	.3618	9.406	623.2	.3574	9.099	622.9	.3532	20
30	9.966	629.1	.3733	9.633	628.8	.3691	9.321	628.5	.3649	30
40	10.20	634.6	.3845	9.858	634.4	.3803	9.540	634.1	.3762	40
50	10.43	640.1	1.3953	10.08	639.9	1.3912	9.757	639.6	1.3871	50
60	10.65	645.5	.4059	10.30	645.3	.4017	9.972	645.1	.3977	60
70	10.88	650.9	.4161	10.52	650.7	.4120	10.18	650.5	.4080	70
80	11.10	656.2	.4261	10.74	656.1	.4221	10.40	655.9	.4181	80
90	11.33	661.6	.4359	10.96	661.4	.4319	10.61	661.2	.4280	90
100	11.55	666.9	1.4456	11.17	666.7	1.4415	10.81	666.6	1.4376	100
110	11.77	672.2	.4550	11.38	672.1	.4510	11.02	671.9	.4470	110
120	11.99	677.5	.4642	11.60	677.4	.4602	11.23	677.3	.4563	120
130	12.21	682.9	.4733	11.81	682.7	.4693	11.44	682.6	.4655	130
140	12.43	688.2	.4823	12.02	688.1	.4783	11.64	687.9	.4744	140
150	12.65	693.5	1.4911	12.23	693.4	1.4871	11.85	693.3	1.4833	150
160	12.87	698.8	.4998	12.44	698.7	.4958	12.05	698.6	.4920	160
170	13.08	704.2	.5083	12.66	704.1	.5044	12.26	704.0	.5006	170
180	13.30	709.6	.5168	12.87	709.5	.5129	12.46	709.4	.5090	180
190	13.52	714.9	.5251	13.07	714.8	.5212	12.66	714.7	.5174	190
200	13.73	720.3	1.5334	13.28	720.2	1.5294	12.86	720.1	1.5256	200
220	14.16	731.1	.5495	13.70	731.1	.5456	13.27	731.0	.5418	220
240	14.59	742.0	.5653	14.12	742.0	.5614	13.67	741.9	.5576	240
260	15.02	753.0	.5808	14.53	752.9	.5769	14.08	752.9	.5731	260
280	15.45	764.1	.5960	14.95	764.0	.5921	14.48	763.9	.5883	280

TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.

[V=volume in ft.<sup>3</sup>/lb.; H=heat content in Btu./lb.; S=entropy in Btu./lb. °F.]

Temp. °F.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)									Temp. °F.
	28 -3.40°			29 -1.97°			30 -0.57°			
	V	H	S	V	H	S	V	H	S	
<i>Sat.</i>	<i>9.858</i>	<i>610.7</i>	<i>1.3481</i>	<i>9.634</i>	<i>611.1</i>	<i>1.3392</i>	<i>9.396</i>	<i>611.6</i>	<i>1.3364</i>	<i>Sat.</i>
0	9.942	612.7	1.3465	9.584	612.3	1.3417	9.250	611.9	1.3371	0
10	10.20	618.4	.3589	9.834	618.1	.3542	9.492	617.8	.3497	10
20	10.45	624.1	.3708	10.08	623.8	.3662	9.731	623.5	.3618	20
30	10.70	629.6	.3822	10.32	629.4	.3777	9.966	629.1	.3733	30
40	10.95	635.1	.3933	10.56	634.9	.3888	10.20	634.6	.3845	40
50	11.19	640.5	1.4041	10.80	640.3	1.3996	10.43	640.1	1.3953	50
60	11.44	645.9	.4145	11.03	645.7	.4101	10.65	645.5	.4059	60
70	11.68	651.2	.4247	11.26	651.1	.4204	10.88	650.9	.4161	70
80	11.92	656.6	.4347	11.50	656.4	.4304	11.10	656.2	.4261	80
90	12.15	661.9	.4445	11.73	661.7	.4401	11.33	661.6	.4359	90
100	12.39	667.2	1.4540	11.96	667.1	1.4497	11.55	666.9	1.4456	100
110	12.63	672.5	.4634	12.18	672.4	.4591	11.77	672.2	.4550	110
120	12.86	677.8	.4726	12.41	677.7	.4684	11.99	677.5	.4642	120
130	13.10	683.1	.4817	12.64	683.0	.4775	12.21	682.9	.4733	130
140	13.33	688.4	.4906	12.86	688.3	.4864	12.43	688.2	.4823	140
150	13.56	693.7	1.4994	13.09	693.6	1.4952	12.65	693.5	1.4911	150
160	13.80	699.1	.5081	13.31	699.0	.5039	12.87	698.8	.4998	160
170	14.03	704.4	.5167	13.54	704.3	.5124	13.08	704.2	.5083	170
180	14.26	709.8	.5251	13.76	709.7	.5209	13.30	709.6	.5168	180
190	14.49	715.1	.5334	13.99	715.0	.5292	13.52	714.9	.5251	190
200	14.72	720.5	1.5416	14.21	720.4	.5374	13.73	720.3	1.5334	200
220	15.18	731.3	.5578	14.65	731.2	.5536	14.16	731.1	.5495	220
240	15.64	742.2	.5736	15.10	742.2	.5694	14.59	742.0	.5653	240
260	16.10	753.2	.5890	15.54	753.1	.5848	15.02	753.0	.5808	260
	33 3.40°			34 4.66°			35 5.89°			
<i>Sat.</i>	<i>8.445</i>	<i>618.8</i>	<i>1.3285</i>	<i>8.211</i>	<i>615.2</i>	<i>1.3260</i>	<i>7.991</i>	<i>615.6</i>	<i>1.3236</i>	<i>Sat.</i>
10	8.592	616.8	1.3369	8.328	616.4	1.3328	8.078	616.1	1.3289	10
20	8.812	622.6	.3492	8.542	622.3	.3452	8.287	622.0	.3413	20
30	9.028	628.3	.3609	8.753	628.0	.3570	8.493	627.7	.3532	30
40	9.242	633.9	.3722	8.960	633.6	.3684	8.695	633.4	.3646	40
50	9.452	639.4	1.3832	9.166	639.2	1.3793	8.895	638.9	1.3756	50
60	9.661	644.9	.3938	9.369	644.7	.3900	9.093	644.4	.3863	60
70	9.868	650.3	.4042	9.570	650.1	.4004	9.289	649.9	.3967	70
80	10.07	655.7	.4143	9.770	655.5	.4105	9.484	655.3	.4069	80
90	10.28	661.1	.4241	9.969	660.9	.4204	9.677	660.7	.4168	90
100	10.48	666.4	1.4338	10.17	666.3	1.4301	9.869	666.1	1.4265	100
110	10.68	671.8	.4433	10.36	671.6	.4396	10.06	671.5	.4360	110
120	10.88	677.1	.4526	10.56	677.0	.4489	10.25	676.8	.4453	120
130	11.08	682.5	.4617	10.75	682.3	.4581	10.44	682.2	.4545	130
140	11.28	687.8	.4707	10.95	687.7	.4671	10.63	687.6	.4635	140
150	11.48	693.2	1.4795	11.14	693.0	1.4759	10.82	692.9	1.4724	150
160	11.68	698.5	.4883	11.33	698.4	.4846	11.00	698.3	.4811	160
170	11.88	703.9	.4968	11.53	703.8	.4932	11.19	703.7	.4897	170
180	12.08	709.3	.5053	11.72	709.2	.5017	11.38	709.1	.4982	180
190	12.27	714.6	.5137	11.91	714.5	.5101	11.56	714.5	.5066	190
200	12.47	720.0	1.5219	12.10	720.0	1.5183	11.75	719.9	1.5148	200
220	12.86	730.9	.5381	12.48	730.8	.5346	12.12	730.7	.5311	220
240	13.26	741.8	.5540	12.86	741.7	.5504	12.49	741.7	.5469	240
260	13.65	752.8	.5695	13.24	752.7	.5659	12.86	752.7	.5624	260
280	14.04	763.9	.5846	13.62	763.8	.5811	13.23	763.7	.5776	280

TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.

[V=volume in ft.<sup>3</sup>/lb.; H=heat content in Btu./lb.; S=entropy in Btu./lb. °F.]

Temp. °F.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)									Temp. °F.
	35 5.89°			36 7.09°			37 8.27°			
	V	H	S	V	H	S	V	H	S	
Sat.	7.991	615.6	1.3236	7.783	614.0	1.3213	7.584	614.5	1.3190	Sat.
10	8.078	616.1	1.3289	7.842	615.7	1.3250	7.619	615.4	1.3212	10
20	8.287	622.0	.3413	8.046	621.7	.3375	7.819	621.4	.3338	20
30	8.493	627.7	.3532	8.247	627.4	.3494	8.015	627.2	.3458	30
40	8.695	633.4	.3646	8.445	633.1	.3609	8.208	632.9	.3573	40
50	8.895	638.9	1.3756	8.640	638.7	1.3720	8.398	638.5	1.3684	50
60	9.093	644.4	.3863	8.833	644.2	.3827	8.587	644.0	.3792	60
70	9.289	649.9	.3967	9.024	649.7	.3932	8.773	649.5	.3897	70
80	9.484	655.3	.4069	9.214	655.2	.4033	8.958	655.0	.3999	80
90	9.677	660.7	.4168	9.402	660.6	.4133	9.142	660.4	.4098	90
100	9.869	666.1	1.4265	9.589	666.0	1.4230	9.324	665.8	1.4196	100
110	10.06	671.5	.4360	9.775	671.3	.4325	9.506	671.2	.4291	110
120	10.25	676.8	.4453	9.961	676.7	.4419	9.686	676.6	.4385	120
130	10.44	682.2	.4545	10.15	682.1	.4510	9.866	681.9	.4477	130
140	10.63	687.6	.4635	10.33	687.4	.4601	10.05	687.3	.4567	140
150	10.82	692.9	1.4724	10.51	692.8	1.4689	10.22	692.7	1.4656	150
160	11.00	698.3	.4811	10.69	698.2	.4777	10.40	698.1	.4744	160
170	11.19	703.7	.4897	10.88	703.6	.4863	10.58	703.5	.4830	170
180	11.38	709.1	.4982	11.06	709.0	.4948	10.76	708.9	.4915	180
190	11.56	714.5	.5066	11.24	714.4	.5032	10.93	714.3	.4999	190
200	11.75	719.9	1.5148	11.42	719.8	1.5115	11.11	719.7	1.5082	200
220	12.12	730.7	.5311	11.78	730.6	.5277	11.46	730.6	.5244	220
240	12.49	741.7	.5469	12.14	741.6	.5436	11.81	741.5	.5403	240
260	12.86	752.7	.5624	12.50	752.6	.5591	12.16	752.5	.5558	260
280	13.23	763.7	.5776	12.86	763.7	.5743	12.51	763.6	.5710	280
	40 11.66°			42 13.81°			44 15.88°			
Sat.	7.047	616.4	1.3126	6.751	616.0	1.3084	6.442	616.6	1.3046	Sat.
20	7.203	620.4	1.3231	6.842	619.8	1.3164	6.513	619.1	1.3099	20
30	7.387	626.3	.3353	7.019	625.8	.3287	6.683	625.2	.3224	30
40	7.568	632.1	.3470	7.192	631.6	.3405	6.850	631.1	.3343	40
50	7.746	637.8	1.3583	7.363	637.3	1.3519	7.014	638.8	1.3457	50
60	7.922	643.4	.3692	7.531	643.0	.3628	7.176	642.5	.3567	60
70	8.096	648.9	.3797	7.697	648.5	.3734	7.336	648.1	.3674	70
80	8.268	654.4	.3900	7.862	654.1	.3838	7.494	653.7	.3778	80
90	8.439	659.9	.4000	8.026	659.5	.3939	7.650	659.2	.3880	90
100	8.609	665.3	1.4098	8.188	665.0	1.4037	7.806	664.7	1.3978	100
110	8.777	670.7	.4194	8.349	670.4	.4133	7.960	670.1	.4075	110
120	8.945	676.1	.4288	8.510	675.9	.4228	8.114	675.6	.4170	120
130	9.112	681.5	.4381	8.669	681.3	.4320	8.267	681.0	.4263	130
140	9.278	686.9	.4471	8.828	686.7	.4411	8.419	686.4	.4354	140
150	9.444	692.3	1.4561	8.986	692.1	1.4501	8.570	691.9	1.4444	150
160	9.609	697.7	.4648	9.144	697.5	.4589	8.721	697.3	.4532	160
170	9.774	703.1	.4735	9.301	702.9	.4676	8.871	702.7	.4619	170
180	9.938	708.5	.4820	9.458	708.3	.4761	9.021	708.1	.4704	180
190	10.10	714.0	.4904	9.614	713.8	.4845	9.171	713.6	.4789	190
200	10.27	719.4	1.4987	9.770	719.2	1.4928	9.320	719.0	1.4872	200
220	10.59	730.3	.5150	10.08	730.1	.5091	9.617	730.0	.5035	220
240	10.92	741.3	.5309	10.39	741.1	.5251	9.913	741.0	.5195	240
260	11.24	752.3	.5465	10.70	752.2	.5406	10.21	752.0	.5350	260
280	11.56	763.4	.5617	11.01	763.3	.5559	10.50	763.1	.5503	280
300	11.88	774.6	.5766	11.31	774.5	1.5708	10.80	774.3	1.5652	300

**TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.**

[V—volume in ft.<sup>3</sup>/lb.; H—heat content in Btu./lb.; S—entropy in Btu./lb. °F.]

Temp. °F.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)									Temp. °F.
	38 <i>9.45°</i>			39 <i>10.55°</i>			40 <i>11.66°</i>			
	V	H	S	V	H	S	V	H	S	
Sat.	7.396	614.7	1.3168	7.217	615.0	1.3148	7.047	615.4	1.3125	Sat.
10	7.407	615.0	1.3175	7.398	620.7	1.3266	7.203	620.4	1.3231	10
20	7.603	621.0	.3301	7.586	626.6	.3387	7.387	626.3	.3353	20
30	7.795	626.9	.3422	7.770	632.4	.3504	7.568	632.1	.3470	30
40	7.983	632.6	.3538	7.952	638.0	1.3616	7.746	637.8	1.3583	40
50	8.170	638.3	1.3650	8.132	643.6	.3724	7.922	643.4	.3692	50
60	8.353	643.8	.3758	8.310	649.1	.3830	8.096	648.9	.3797	60
70	8.535	649.3	.3863	8.486	654.6	.3932	8.268	654.4	.3900	70
80	8.716	654.8	.3965	8.661	660.1	.4032	8.439	659.9	.4000	80
90	8.895	660.2	.4065	8.835	665.5	1.4130	8.609	665.3	1.4098	90
100	9.073	665.6	1.4163	9.008	670.9	.4226	8.777	670.7	.4194	100
110	9.250	671.0	.4258	9.179	676.3	.4320	8.945	676.1	.4288	110
120	9.426	676.4	.4352	9.351	681.7	.4412	9.112	681.5	.4381	120
130	9.602	681.8	.4444	9.521	687.1	.4503	9.278	686.9	.4471	130
140	9.776	687.2	.4534	9.691	692.5	1.4592	9.444	692.3	1.4561	140
150	9.950	692.6	1.4623	9.860	697.8	.4679	9.609	697.7	.4648	150
160	10.12	698.0	.4711	10.03	703.2	.4766	9.774	703.1	.4735	160
170	10.30	703.3	.4797	10.20	708.6	.4851	9.938	708.5	.4820	170
180	10.47	708.7	.4883	10.36	714.1	.4935	10.10	714.0	.4904	180
190	10.64	714.2	.4966	10.53	719.5	1.5018	10.27	719.4	1.4987	190
200	10.81	719.6	1.5049	10.87	730.4	.5181	10.59	730.3	.5159	200
220	11.16	730.5	.5212	11.20	741.3	.5340	10.92	741.3	.5309	220
240	11.50	741.4	.5371	11.53	752.4	.5495	11.24	752.3	.5465	240
260	11.84	752.4	.5526	11.86	763.5	.5647	11.56	763.4	.5617	260
280	12.18	763.5	.5678							280
	46 <i>17.87°</i>			48 <i>19.30°</i>			50 <i>21.67°</i>			
Sat.	6.177	617.2	1.3009	5.934	617.7	1.2973	5.710	618.2	1.2939	Sat.
20	6.213	618.5	1.3036	6.096	624.0	.3103	5.838	623.4	1.3046	20
30	6.377	624.6	.3192	6.251	630.0	.3225	5.988	629.5	.3169	30
40	6.538	630.5	.3283	6.404	635.9	1.3341	6.135	635.4	1.3286	40
50	6.696	636.4	1.3398	6.554	641.6	.3453	6.280	641.2	.3399	50
60	6.851	642.1	.3509	6.702	647.3	.3561	6.423	646.9	.3508	60
70	7.005	647.7	.3617	6.848	652.9	.3666	6.564	652.6	.3613	70
80	7.157	653.3	.3721	6.993	658.5	.3768	6.704	658.2	.3716	80
90	7.308	658.9	.3823	7.137	664.0	1.3868	6.843	663.7	1.3816	90
100	7.457	664.4	1.3922	7.280	669.5	.3965	6.980	669.2	.3914	100
110	7.605	669.8	.4019	7.421	675.0	.4061	7.117	674.7	.4009	110
120	7.753	675.3	.4114	7.562	680.5	.4154	7.252	680.2	.4103	120
130	7.899	680.7	.4207	7.702	685.9	.4246	7.387	685.7	.4195	130
140	8.045	686.2	.4299	7.842	691.4	1.4336	7.521	691.1	1.4286	140
150	8.190	691.6	1.4389	7.981	696.8	.4425	7.655	696.6	.4374	150
160	8.335	697.1	.4477	8.119	702.3	.4512	7.788	702.1	.4462	160
170	8.479	702.5	.4564	8.257	707.7	.4598	7.921	707.5	.4548	170
180	8.623	707.9	.4650	8.395	713.2	.4683	8.053	713.0	.4633	180
190	8.766	713.4	.4735	8.532	718.7	1.4766	8.185	718.5	1.4716	190
200	8.909	718.8	1.4818	8.670	724.2	.4850	8.317	724.0	.4800	200
220	9.194	729.8	.4981	8.805	729.6	.4930	8.448	729.4	.4880	220
240	9.477	740.8	.5141	8.937	740.6	.5090	8.710	740.5	.5040	240
260	9.760	751.9	.5297	9.069	751.7	.5246	8.970	751.6	.5197	260
280	10.04	763.0	.5450	9.619	762.9	.5399	9.230	762.7	.5350	280
300	10.32	774.2	1.5599	9.888	774.1	1.5548	9.489	774.0	1.5500	300

TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.

[V—volume in ft.<sup>3</sup>/lb.; H—heat content in Btu./lb.; S—entropy in Btu./lb. °F.]

Temp. °F.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperatures in italics.)									Temp. °F.
	50 <i>21.67°</i>			52 <i>23.48°</i>			54 <i>25.23°</i>			
	V	H	S	V	H	S	V	H	S	
<i>Sat.</i>	<i>6.710</i>	<i>618.3</i>	<i>1.2359</i>	<i>6.508</i>	<i>618.7</i>	<i>1.2306</i>	<i>6.309</i>	<i>619.3</i>	<i>1.2276</i>	<i>Sat.</i>
30	5.838	623.4	1.3046	5.599	622.8	1.2991	5.378	622.2	1.2937	30
40	5.988	629.5	.3169	5.744	629.0	.3114	5.519	628.4	.3062	40
50	6.135	635.4	1.3286	5.887	634.9	1.3233	5.657	634.4	1.3181	50
60	6.280	641.2	.3399	6.027	640.8	.3346	5.793	640.3	.3295	60
70	6.423	646.9	.3508	6.165	646.5	.3456	5.927	646.1	.3406	70
80	6.564	652.6	.3613	6.302	652.2	.3562	6.059	651.8	.3513	80
90	6.704	658.2	.3716	6.437	657.8	.3665	6.190	657.5	.3616	90
100	6.843	663.7	1.3816	6.571	663.4	1.3766	6.319	663.1	1.3717	100
110	6.980	669.2	.3914	6.704	668.9	.3864	6.447	668.6	.3816	110
120	7.117	674.7	.4009	6.835	674.4	.3960	6.575	674.2	.3912	120
130	7.252	680.2	.4103	6.966	679.9	.4054	6.701	679.7	.4006	130
140	7.387	685.7	.4195	7.096	685.4	.4146	6.827	685.2	.4099	140
150	7.521	691.1	1.4286	7.225	690.9	1.4237	6.952	690.7	1.4190	150
160	7.655	696.6	.4374	7.354	696.4	.4326	7.076	696.1	.4279	160
170	7.788	702.1	.4462	7.483	701.8	.4413	7.200	701.6	.4367	170
180	7.921	707.5	.4548	7.611	707.3	.4500	7.323	707.1	.4453	180
190	8.053	713.0	.4633	7.738	712.8	.4585	7.446	712.6	.4538	190
200	8.185	718.5	1.4716	7.865	718.3	1.4668	7.569	718.1	1.4622	200
210	8.317	724.0	.4799	7.992	723.8	.4751	7.691	723.6	.4705	210
220	8.448	729.4	.4880	8.118	729.3	.4833	7.813	729.1	.4787	220
240	8.710	740.5	.5040	8.370	740.3	.4993	8.056	740.2	.4947	240
260	8.970	751.6	.5197	8.621	751.4	.5149	8.298	751.3	.5104	260
280	9.230	762.7	1.5350	8.871	762.6	1.5303	8.539	762.5	1.5257	280
300	9.489	774.0	.5500	9.120	773.8	.5453	8.779	773.7	.5407	300
	60 <i>30.21°</i>			62 <i>31.78°</i>			64 <i>33.31°</i>			
<i>Sat.</i>	<i>4.806</i>	<i>680.5</i>	<i>1.2787</i>	<i>4.668</i>	<i>680.9</i>	<i>1.2759</i>	<i>4.519</i>	<i>681.3</i>	<i>1.2733</i>	<i>Sat.</i>
40	4.933	626.8	1.2913	4.762	626.2	1.2866	4.602	625.6	1.2820	40
50	5.060	632.9	1.3035	4.886	632.4	1.2989	4.723	631.9	1.2944	50
60	5.184	639.0	.3152	5.007	638.5	.3107	4.842	638.0	.3063	60
70	5.307	644.9	.3265	5.127	644.4	.3220	4.958	644.0	.3177	70
80	5.428	650.7	.3373	5.244	650.3	.3330	5.072	649.9	.3287	80
90	5.547	656.4	.3479	5.360	656.0	.3435	5.185	655.7	.3393	90
100	5.665	662.1	1.3581	5.474	661.7	1.3538	5.296	661.4	1.3496	100
110	5.781	667.7	.3681	5.588	667.4	.3638	5.406	667.1	.3597	110
120	5.897	673.3	.3778	5.700	673.0	.3736	5.516	672.7	.3695	120
130	6.012	678.9	.3873	5.811	678.6	.3831	5.624	678.3	.3791	130
140	6.126	684.4	.3966	5.922	684.2	.3925	5.731	683.9	.3885	140
150	6.239	689.9	1.4058	6.032	689.7	1.4017	5.838	689.5	1.3977	150
160	6.352	695.5	.4148	6.142	695.2	.4107	5.944	695.0	.4067	160
170	6.464	701.0	.4236	6.250	700.8	.4195	6.050	700.5	.4156	170
180	6.576	706.5	.4323	6.359	706.3	.4282	6.155	706.1	.4243	180
190	6.687	712.0	.4409	6.467	711.8	.4368	6.260	711.6	.4329	190
200	6.798	717.5	1.4493	6.574	717.3	1.4453	6.364	717.2	1.4413	200
210	6.909	723.1	.4576	6.681	722.9	.4536	6.468	722.7	.4497	210
220	7.019	728.6	.4658	6.788	728.4	.4618	6.572	728.3	.4579	220
230	7.129	734.1	.4739	6.895	734.0	.4699	6.675	733.8	.4660	230
240	7.238	739.7	.4819	7.001	739.5	.4779	6.778	739.4	.4741	240
260	7.457	750.9	1.4976	7.213	750.7	1.4937	6.984	750.6	1.4898	260
280	7.675	762.1	.5130	7.424	761.9	.5091	7.188	761.8	.5052	280
300	7.892	773.3	.5281	7.634	773.2	.5241	7.392	773.1	.5203	300

TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.

[V= volume in ft.<sup>3</sup>/lb.; H= heat content in Btu./lb.; S= entropy in Btu./lb. °F.]

Temp. °F.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)									Temp. °F.
	56 <i>26.34°</i>			58 <i>28.59°</i>			60 <i>30.81°</i>			
	V	H	S	V	H	S	V	H	S	
<i>Sat.</i>	<i>5.129</i>	<i>619.7</i>	<i>1.2844</i>	<i>4.962</i>	<i>620.1</i>	<i>1.2815</i>	<i>4.805</i>	<i>620.5</i>	<i>1.2787</i>	<i>Sat.</i>
30	5.172	621.6	1.2884	4.981	621.0	1.2834	4.833	622.8	1.2813	30
40	5.310	627.9	.3011	5.115	627.3	.2961	5.060	632.9	1.3035	40
50	5.444	633.9	1.3131	5.245	633.4	1.3082	5.184	639.0	.3152	50
60	5.576	639.9	.3246	5.373	639.4	.3199	5.307	644.9	.3265	60
70	5.706	645.7	.3357	5.499	645.3	.3310	5.428	650.7	.3373	70
80	5.834	651.4	.3465	5.624	651.1	.3418	5.547	656.4	.3479	80
90	5.960	657.1	.3569	5.746	656.8	.3523	5.665	662.1	1.3581	90
100	6.085	662.7	1.3670	5.868	662.4	1.3625	5.781	667.7	.3681	100
110	6.209	668.3	.3769	5.988	668.0	.3724	5.897	673.3	.3778	110
120	6.333	673.9	.3866	6.107	673.6	.3821	6.012	678.9	.3873	120
130	6.455	679.4	.3961	6.226	679.1	.3916	6.126	684.4	.3966	130
140	6.576	684.9	.4053	6.343	684.7	.4009	6.239	689.9	1.4058	140
150	6.697	690.4	1.4144	6.460	690.2	1.4100	6.352	695.5	.4148	150
160	6.817	695.9	.4234	6.577	695.7	.4190	6.464	701.0	.4236	160
170	6.937	701.4	.4322	6.692	701.2	.4278	6.576	706.5	.4323	170
180	7.056	706.9	.4408	6.808	706.7	.4365	6.687	712.0	.4409	180
190	7.175	712.4	.4494	6.923	712.2	.4450	6.798	717.5	1.4493	190
200	7.294	717.9	1.4578	7.037	717.7	1.4535	6.909	723.1	.4576	200
210	7.412	723.4	.4661	7.151	723.2	.4618	7.019	728.6	.4658	210
220	7.529	728.9	.4743	7.265	728.8	.4700	7.126	734.1	.4741	220
240	7.764	740.0	.4903	7.492	739.9	.4860	7.238	739.7	.4819	240
260	7.998	751.1	.5060	7.718	751.0	.5017	7.347	745.2	.4896	260
280	8.230	762.3	1.5213	7.943	762.2	.5171	7.457	750.9	1.5130	280
300	8.462	773.6	.5364	8.167	773.5	.5321	7.567	756.6	.5281	300
	66 <i>34.81°</i>			68 <i>36.97°</i>			70 <i>37.70°</i>			
<i>Sat.</i>	<i>4.389</i>	<i>631.7</i>	<i>1.2707</i>	<i>4.267</i>	<i>629.0</i>	<i>1.2638</i>	<i>4.161</i>	<i>628.4</i>	<i>1.2653</i>	<i>Sat.</i>
40	4.452	625.1	1.2775	4.310	624.5	1.2731	4.177	623.9	1.2688	40
50	4.570	631.4	1.2900	4.426	630.9	1.2858	4.290	630.4	1.2816	50
60	4.686	637.6	.3020	4.539	637.1	.2978	4.401	636.6	.2937	60
70	4.799	643.6	.3135	4.650	643.2	.3094	4.509	642.7	.3054	70
80	4.910	649.5	.3245	4.758	649.1	.3205	4.615	648.7	.3166	80
90	5.020	655.3	.3352	4.865	655.0	.3312	4.719	654.6	.3274	90
100	5.129	661.1	1.3456	4.971	660.7	1.3417	4.822	660.4	1.3378	100
110	5.236	666.8	.3557	5.075	666.5	.3518	4.924	666.1	.3480	110
120	5.342	672.4	.3655	5.179	672.1	.3617	5.025	671.8	.3579	120
130	5.447	678.0	.3751	5.281	677.8	.3713	5.125	677.5	.3676	130
140	5.552	683.6	.3846	5.383	683.4	.3807	5.224	683.1	.3770	140
150	5.656	689.2	1.3938	5.484	689.0	1.3900	5.323	688.7	1.3863	150
160	5.759	694.8	.4028	5.585	694.5	.3991	5.420	694.3	.3954	160
170	5.862	700.3	.4117	5.685	700.1	.4080	5.518	699.9	.4043	170
180	5.964	705.9	.4205	5.784	705.7	.4167	5.615	705.5	.4131	180
190	6.066	711.4	.4291	5.883	711.2	.4254	5.711	711.0	.4217	190
200	6.167	717.0	1.4375	5.982	716.8	1.4338	5.807	716.6	1.4302	200
210	6.268	722.5	.4459	6.080	722.3	.4422	5.902	722.2	.4386	210
220	6.369	728.1	.4541	6.179	727.9	.4505	5.998	727.7	.4469	220
230	6.470	733.7	.4623	6.275	733.5	.4586	6.093	733.3	.4550	230
240	6.570	739.2	.4703	6.373	739.1	.4666	6.187	738.9	.4631	240
260	6.769	750.4	1.4861	6.567	750.3	1.4824	6.376	750.1	1.4789	260
280	6.968	761.7	.5015	6.760	761.5	.4979	6.563	761.4	.4943	280
300	7.165	773.0	.5166	6.952	772.8	.5130	6.750	772.7	.5095	300

TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.

[V=volume in ft.<sup>3</sup>/lb.; H=heat content in Btu./lb.; S=entropy in Btu./lb. °F.]

Temp. °F.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)									Temp. °F.
	75 41.15°			80 44.40°			85 47.60°			
	V	H	S	V	H	S	V	H	S	
Sat.	3.887	683.2	1.2599	3.655	684.0	1.2545	3.449	684.7	1.2494	Sat.
50	3.982	629.1	1.2715	3.712	627.7	1.2619	3.473	626.4	1.2527	50
60	4.087	635.5	.2839	3.812	634.3	.2745	3.569	633.0	.2656	60
70	4.189	641.7	.2957	3.909	640.6	.2866	3.662	639.5	.2779	70
80	4.289	647.7	.3071	4.005	646.7	.2981	3.753	645.7	.2896	80
90	4.388	653.7	.3180	4.098	652.8	.3092	3.842	651.8	.3008	90
100	4.485	659.6	1.3286	4.190	658.7	1.3199	3.930	657.8	1.3117	100
110	4.581	665.4	.3389	4.281	664.6	.3303	4.016	663.8	.3221	110
120	4.676	671.1	.3489	4.371	670.4	.3404	4.101	669.6	.3323	120
130	4.770	676.8	.3586	4.460	676.1	.3502	4.186	675.4	.3422	130
140	4.863	682.5	.3682	4.548	681.8	.3598	4.269	681.2	.3519	140
150	4.956	688.1	1.3775	4.635	687.5	1.3692	4.352	686.9	1.3614	150
160	5.048	693.7	.3866	4.722	693.2	.3784	4.434	692.6	.3706	160
170	5.139	699.3	.3956	4.808	698.8	.3874	4.515	698.2	.3797	170
180	5.230	704.9	.4044	4.893	704.4	.3963	4.596	703.9	.3886	180
190	5.320	710.5	.4131	4.978	710.0	.4050	4.677	709.5	.3974	190
200	5.410	716.1	1.4217	5.063	715.6	1.4136	4.757	715.2	1.4060	200
210	5.500	721.7	.4301	5.147	721.3	.4220	4.836	720.8	.4145	210
220	5.589	727.3	.4384	5.231	726.9	.4304	4.916	726.4	.4228	220
230	5.678	732.9	.4466	5.315	732.5	.4386	4.995	732.1	.4311	230
240	5.767	738.5	.4546	5.398	738.1	.4467	5.074	737.7	.4392	240
250	5.855	744.1	1.4625	5.482	743.8	1.4547	5.152	743.4	1.4472	250
260	5.943	749.8	.4705	5.565	749.4	.4626	5.230	749.0	.4551	260
280	6.119	761.1	.4860	5.730	760.7	.4781	5.386	760.4	.4707	280
300	6.294	772.4	.5011	5.894	772.1	.4933	5.541	771.8	.4859	300
	100 58.06°			105 58.67°			110 61.21°			
Sat.	3.968	695.5	1.2566	3.817	687.0	1.2514	3.683	687.5	1.2475	Sat.
70	3.068	636.0	1.2539	2.907	634.9	1.2464	2.761	633.7	1.2392	70
80	3.149	642.6	.2661	2.985	641.5	.2589	2.837	640.5	.2519	80
90	3.227	649.0	.2778	3.061	648.0	.2708	2.910	647.0	.2640	90
100	3.304	655.2	1.2891	3.135	654.3	1.2822	2.981	653.4	1.2755	100
110	3.380	661.3	.2999	3.208	660.5	.2931	3.051	659.7	.2866	110
120	3.454	667.3	.3104	3.279	666.6	.3037	3.120	665.8	.2972	120
130	3.527	673.3	.3206	3.350	672.6	.3139	3.188	671.9	.3076	130
140	3.600	679.2	.3305	3.419	678.5	.3239	3.255	677.8	.3176	140
150	3.672	685.0	1.3401	3.488	684.4	1.3336	3.321	683.7	1.3274	150
160	3.743	690.8	.3495	3.556	690.2	.3431	3.386	689.6	.3370	160
170	3.813	696.6	.3588	3.623	696.0	.3524	3.451	695.4	.3463	170
180	3.883	702.3	.3678	3.690	701.8	.3615	3.515	701.2	.3555	180
190	3.952	708.0	.3767	3.757	707.5	.3704	3.579	707.0	.3644	190
200	4.021	713.7	1.3854	3.823	713.3	1.3792	3.642	712.8	1.3732	200
210	4.090	719.4	.3940	3.888	719.0	.3878	3.705	718.5	.3819	210
220	4.158	725.1	.4024	3.954	724.7	.3963	3.768	724.3	.3904	220
230	4.226	730.8	.4108	4.019	730.4	.4046	3.830	730.0	.3988	230
240	4.294	736.5	.4190	4.083	736.1	.4129	3.892	735.7	.4070	240
250	4.361	742.2	1.4271	4.148	741.9	1.4210	3.954	741.5	1.4151	250
260	4.428	747.9	.4350	4.212	747.6	.4290	4.015	747.2	.4232	260
270	4.495	753.6	.4429	4.276	753.3	.4369	4.076	752.9	.4311	270
280	4.562	759.4	.4507	4.340	759.0	.4447	4.137	758.7	.4389	280
290	4.629	765.1	.4584	4.403	764.8	.4524	4.198	764.5	.4466	290
300	4.695	770.8	1.4660	4.466	770.5	1.4600	4.259	770.2	1.4543	300

TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.

[V=volume in ft.<sup>3</sup>/lb.; H=heat content in Btu./lb.; S=entropy in Btu./lb. °F.]

Temp. °F.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)									Temp. °F.
	90 <i>60.47°</i>			95 <i>63.38°</i>			100 <i>66.06°</i>			
	V	H	S	V	H	S	V	H	S	
<i>Sat.</i>	<i>3.806</i>	<i>626.3</i>	<i>1.2445</i>	<i>3.101</i>	<i>626.9</i>	<i>1.2390</i>	<i>2.968</i>	<i>626.5</i>	<i>1.2366</i>	<i>Sat.</i>
50										50
60	3.353	631.8	1.2571	3.160	630.5	1.2489	2.985	629.3	1.2409	60
70	3.442	638.3	.2695	3.245	637.2	.2616	3.068	636.0	.2539	70
80	3.529	644.7	.2814	3.329	643.6	.2736	3.149	642.6	.2661	80
90	3.614	650.9	.2928	3.411	649.9	.2852	3.227	649.0	.2778	90
100	3.698	657.0	1.3038	3.491	656.1	1.2963	3.304	655.2	1.2891	100
110	3.780	663.0	.3144	3.570	662.1	.3070	3.380	661.3	.2999	110
120	3.862	668.9	.3247	3.647	668.1	.3174	3.454	667.3	.3104	120
130	3.942	674.7	.3347	3.724	674.0	.3275	3.527	673.3	.3206	130
140	4.021	680.5	.3444	3.799	679.8	.3373	3.600	679.2	.3305	140
150	4.100	686.3	1.3539	3.874	685.6	1.3469	3.672	685.0	1.3401	150
160	4.178	692.0	.3633	3.949	691.4	.3562	3.743	690.8	.3495	160
170	4.255	697.7	.3724	4.022	697.1	.3654	3.813	696.6	.3588	170
180	4.332	703.4	.3813	4.096	702.8	.3744	3.883	702.3	.3678	180
190	4.408	709.0	.3901	4.168	708.5	.3833	3.952	708.0	.3767	190
200	4.484	714.7	1.3988	4.241	714.2	1.3919	4.021	713.7	1.3854	200
210	4.560	720.4	.4073	4.313	719.9	.4005	4.090	719.4	.3940	210
220	4.635	726.0	.4157	4.384	725.6	.4089	4.158	725.1	.4024	220
230	4.710	731.7	.4239	4.455	731.3	.4172	4.226	730.8	.4108	230
240	4.785	737.3	.4321	4.526	736.9	.4254	4.294	736.5	.4190	240
250	4.859	743.0	1.4401	4.597	742.6	1.4334	4.361	742.2	1.4271	250
260	4.933	748.7	.4481	4.668	748.3	.4414	4.428	747.9	.4350	260
280	5.061	760.0	.4637	4.808	759.7	.4570	4.562	759.4	.4507	280
300	5.228	771.5	.4789	4.947	771.2	.4723	4.695	770.8	.4660	300
	115 <i>63.65°</i>			120 <i>66.08°</i>			125 <i>68.31°</i>			
<i>Sat.</i>	<i>2.580</i>	<i>628.0</i>	<i>1.2237</i>	<i>2.476</i>	<i>628.4</i>	<i>1.2201</i>	<i>2.380</i>	<i>628.8</i>	<i>1.2166</i>	<i>Sat.</i>
70	2.628	632.5	1.2323	2.505	631.3	1.2255	2.392	630.0	1.2189	70
80	2.701	639.4	.2451	2.576	638.3	.2386	2.461	637.2	.2322	80
90	2.772	646.0	.2574	2.645	645.0	.2510	2.528	644.0	.2448	90
100	2.841	652.5	1.2690	2.712	651.6	1.2628	2.593	650.7	1.2568	100
110	2.909	658.8	.2802	2.778	658.0	.2741	2.657	657.1	.2682	110
120	2.975	665.0	.2910	2.842	664.2	.2850	2.719	663.5	.2792	120
130	3.040	671.1	.3015	2.905	670.4	.2956	2.780	669.7	.2899	130
140	3.105	677.2	.3116	2.967	676.5	.3058	2.840	675.8	.3002	140
150	3.168	683.1	1.3215	3.029	682.5	1.3157	2.900	681.8	1.3102	150
160	3.231	689.0	.3311	3.089	688.4	.3254	2.958	687.8	.3199	160
170	3.294	694.9	.3405	3.149	694.3	.3348	3.016	693.7	.3294	170
180	3.355	700.7	.3497	3.209	700.2	.3441	3.074	699.6	.3387	180
190	3.417	706.5	.3587	3.268	706.0	.3531	3.131	705.5	.3478	190
200	3.477	712.3	1.3675	3.326	711.8	1.3620	3.187	711.3	1.3567	200
210	3.538	718.1	.3762	3.385	717.6	.3707	3.243	717.2	.3654	210
220	3.598	723.8	.3847	3.442	723.4	.3793	3.299	723.0	.3740	220
230	3.658	729.6	.3931	3.500	729.2	.3877	3.354	728.8	.3825	230
240	3.717	735.3	.4014	3.557	734.9	.3960	3.409	734.5	.3908	240
250	3.776	741.1	1.4096	3.614	740.7	1.4042	3.464	740.3	1.3990	250
260	3.835	746.8	.4176	3.671	746.5	.4123	3.519	746.1	.4071	260
270	3.894	752.6	.4256	3.727	752.2	.4202	3.573	751.9	.4151	270
280	3.952	758.4	.4334	3.783	758.0	.4281	3.627	757.7	.4230	280
290	4.011	764.1	.4411	3.839	763.8	.4359	3.681	763.5	.4308	290
300	4.069	769.9	1.4488	3.895	769.6	1.4435	3.735	769.3	1.4385	300

TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.

[V=volume in ft.<sup>3</sup>/lb.; H=heat content in Btu./lb.; S=entropy in Btu./lb. °F.]

Temp. °F.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)									Temp. °F.
	125 <i>68.31°</i>			130 <i>70.45°</i>			135 <i>71.69°</i>			
	V	H	S	V	H	S	V	H	S	
<i>Sat.</i>	<i>1.530</i>	<i>638.3</i>	<i>1.3106</i>	<i>1.501</i>	<i>639.2</i>	<i>1.3133</i>	<i>1.500</i>	<i>639.3</i>	<i>1.3100</i>	<i>Sat.</i>
80	2.461	637.2	1.2322	2.355	636.0	1.2260	2.257	634.9	1.2199	80
90	2.528	644.0	.2448	2.421	643.0	.2388	2.321	642.0	.2329	90
100	2.593	650.7	1.2568	2.484	649.7	1.2509	2.382	648.8	1.2452	100
110	2.657	657.1	.2682	2.546	656.3	.2625	2.442	655.4	.2569	110
120	2.719	663.5	.2792	2.606	662.7	.2736	2.501	661.9	.2681	120
130	2.780	669.7	.2899	2.665	668.9	.2843	2.559	668.2	.2790	130
140	2.840	675.8	.3002	2.724	675.1	.2947	2.615	674.4	.2894	140
150	2.900	681.8	1.3102	2.781	681.2	1.3048	2.671	680.5	1.2996	150
160	2.958	687.8	.3199	2.838	687.2	.3146	2.726	686.6	.3094	160
170	3.016	693.7	.3294	2.894	693.2	.3241	2.780	692.6	.3191	170
180	3.074	699.6	.3387	2.949	699.1	.3335	2.834	698.6	.3284	180
190	3.131	705.5	.3478	3.004	705.0	.3426	2.887	704.5	.3376	190
200	3.187	711.3	1.3567	3.059	710.9	1.3516	2.940	710.4	1.3466	200
210	3.243	717.2	.3654	3.113	716.7	.3604	2.992	716.2	.3554	210
220	3.299	723.0	.3740	3.167	722.5	.3690	3.044	722.1	.3641	220
230	3.354	728.8	.3825	3.220	728.3	.3775	3.096	727.9	.3726	230
240	3.409	734.5	.3908	3.273	734.1	.3858	3.147	733.7	.3810	240
250	3.464	740.3	1.3990	3.326	739.9	1.3941	3.198	739.6	1.3893	250
260	3.519	746.1	.4071	3.379	745.7	.4022	3.249	745.4	.3974	260
270	3.573	751.9	.4151	3.431	751.5	.4102	3.300	751.2	.4054	270
280	3.627	757.7	.4230	3.483	757.3	.4181	3.350	757.0	.4133	280
290	3.681	763.5	.4308	3.535	763.1	.4259	3.400	762.8	.4212	290
300	3.735	769.3	1.4385	3.587	769.0	1.4336	3.450	768.6	1.4289	300
320	3.842	780.9	.4536	3.690	780.6	.4487	3.550	780.3	.4441	320
	150 <i>78.81°</i>			160 <i>80.64°</i>			170 <i>82.89°</i>			
<i>Sat.</i>	<i>1.994</i>	<i>650.5</i>	<i>1.3009</i>	<i>1.878</i>	<i>651.1</i>	<i>1.1968</i>	<i>1.764</i>	<i>651.6</i>	<i>1.1900</i>	<i>Sat.</i>
90	2.061	638.8	1.2161	1.914	636.6	1.2055	1.784	634.4	1.1952	90
100	2.118	645.9	1.2289	1.969	643.9	1.2186	1.837	641.9	1.2087	100
110	2.174	652.8	.2410	2.023	651.0	.2311	1.889	649.1	.2215	110
120	2.228	659.4	.2526	2.075	657.8	.2429	1.939	656.1	.2336	120
130	2.281	665.9	.2638	2.125	664.4	.2542	1.988	662.8	.2452	130
140	2.334	672.3	.2745	2.175	670.9	.2652	2.035	669.4	.2563	140
150	2.385	678.6	1.2849	2.224	677.2	1.2757	2.081	675.9	1.2669	150
160	2.435	684.8	.2949	2.272	683.5	.2859	2.127	682.3	.2773	160
170	2.485	690.9	.3047	2.319	689.7	.2958	2.172	688.5	.2873	170
180	2.534	696.9	.3142	2.365	695.8	.3054	2.216	694.7	.2971	180
190	2.583	702.9	.3236	2.411	701.9	.3148	2.260	700.8	.3066	190
200	2.631	708.9	1.3327	2.457	707.9	1.3240	2.303	706.9	1.3159	200
210	2.679	714.8	.3416	2.502	713.9	.3331	2.346	713.0	.3249	210
220	2.726	720.7	.3504	2.547	719.9	.3419	2.389	719.0	.3338	220
230	2.773	726.6	.3590	2.591	725.8	.3506	2.431	724.9	.3426	230
240	2.820	732.5	.3675	2.635	731.7	.3591	2.473	730.9	.3512	240
250	2.866	738.4	1.3758	2.679	737.6	1.3675	2.514	736.8	1.3596	250
260	2.912	744.3	.3840	2.723	743.5	.3757	2.555	742.8	.3679	260
270	2.958	750.1	.3921	2.766	749.4	.3838	2.596	748.7	.3761	270
280	3.004	756.0	.4001	2.809	755.3	.3919	2.637	754.6	.3841	280
290	3.049	761.8	.4079	2.852	761.2	.3998	2.678	760.5	.3921	290
300	3.095	767.7	1.4157	2.895	767.1	1.4076	2.718	766.4	1.3999	300
320	3.185	779.4	.4310	2.980	778.9	.4229	2.798	778.3	.4153	320
340	3.274	791.2	.4459	3.064	790.7	.4379	2.878	790.1	.4303	340

TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.

[V=volume in ft.<sup>3</sup>/lb.; H=heat content in Btu./lb.; S=entropy in Btu./lb. °F.]

Temp. °F.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)									Temp. °F.
	140 74.79°			145 76.85°			150 78.81°			
	V	H	S	V	H	S	V	H	S	
Sat.	1.138	689.9	1.8088	1.081	680.8	1.8038	1.094	680.8	1.8009	Sat.
80	2.166	633.8	1.2140	2.080	632.6	1.2082	2.001	631.4	1.2025	80
90	2.228	640.9	.2272	2.141	639.9	.2216	2.061	638.8	.2161	90
100	2.288	647.8	1.2396	2.200	646.9	1.2342	2.118	645.9	1.2289	100
110	2.347	654.5	.2515	2.257	653.6	.2462	2.174	652.8	.2410	110
120	2.404	661.1	.2628	2.313	660.2	.2577	2.228	659.4	.2526	120
130	2.460	667.4	.2738	2.368	666.7	.2687	2.281	665.9	.2638	130
140	2.515	673.7	.2843	2.421	673.0	.2793	2.334	672.3	.2745	140
150	2.569	679.9	1.2945	2.474	679.2	1.2896	2.385	678.6	1.2849	150
160	2.622	686.0	.3045	2.526	685.4	.2996	2.435	684.8	.2949	160
170	2.675	692.0	.3141	2.577	691.4	.3093	2.485	690.9	.3047	170
180	2.727	698.0	.3236	2.627	697.5	.3188	2.534	696.9	.3142	180
190	2.779	704.0	.3328	2.677	703.4	.3281	2.583	702.9	.3236	190
200	2.830	709.9	1.3418	2.727	709.4	1.3372	2.631	708.9	1.3327	200
210	2.880	715.8	.3507	2.776	715.3	.3461	2.679	714.8	.3416	210
220	2.931	721.6	.3594	2.825	721.2	.3548	2.726	720.7	.3504	220
230	2.981	727.5	.3679	2.873	727.1	.3634	2.773	726.6	.3590	230
240	3.030	733.3	.3763	2.921	732.9	.3718	2.820	732.5	.3675	240
250	3.080	739.2	1.3846	2.969	738.8	1.3801	2.866	738.4	1.3758	250
260	3.129	745.0	.3928	3.017	744.6	.3883	2.912	744.3	.3840	260
270	3.179	750.8	.4008	3.064	750.5	.3964	2.958	750.1	.3921	270
280	3.227	756.7	.4088	3.111	756.3	.4043	3.004	756.0	.4001	280
290	3.275	762.5	.4166	3.158	762.2	.4122	3.049	761.8	.4079	290
300	3.323	768.3	1.4243	3.205	768.0	1.4199	3.095	767.7	1.4157	300
320	3.420	780.0	.4395	3.298	779.7	.4352	3.185	779.4	.4310	320
	180 89.78°			190 93.15°			200 96.54°			
Sat.	1.067	638.0	1.1880	1.581	632.4	1.1808	1.508	632.7	1.1766	Sat.
90	1.668	632.2	1.1853							90
100	1.720	639.9	1.1992	1.615	637.8	1.1899	1.520	635.6	1.1809	100
110	1.770	647.3	.2123	1.663	645.4	.2034	1.567	643.4	.1947	110
120	1.818	654.4	.2247	1.710	652.6	.2160	1.612	650.9	.2077	120
130	1.865	661.3	.2364	1.755	659.7	.2281	1.656	658.1	.2200	130
140	1.910	668.0	.2477	1.799	666.5	.2396	1.698	665.0	.2317	140
150	1.955	674.6	1.2586	1.842	673.2	1.2506	1.740	671.8	1.2429	150
160	1.999	681.0	.2691	1.884	679.7	.2612	1.780	678.4	.2537	160
170	2.042	687.3	.2792	1.925	686.1	.2715	1.820	684.9	.2641	170
180	2.084	693.6	.2891	1.966	692.5	.2815	1.859	691.3	.2742	180
190	2.126	699.8	.2987	2.005	698.7	.2912	1.897	697.7	.2840	190
200	2.167	705.9	1.3081	2.045	704.9	1.3007	1.935	703.9	1.2935	200
210	2.208	712.0	.3172	2.084	711.1	.3099	1.972	710.1	.3029	210
220	2.248	718.1	.3262	2.123	717.2	.3189	2.009	716.3	.3120	220
230	2.288	724.1	.3350	2.161	723.2	.3278	2.046	722.4	.3209	230
240	2.328	730.1	.3436	2.199	729.3	.3365	2.082	728.4	.3296	240
250	2.367	736.1	1.3521	2.236	735.3	1.3450	2.118	734.5	1.3382	250
260	2.407	742.0	.3605	2.274	741.3	.3534	2.154	740.5	.3467	260
270	2.446	748.0	.3687	2.311	747.3	.3617	2.189	746.5	.3550	270
280	2.484	753.9	.3768	2.348	753.2	.3698	2.225	752.5	.3631	280
290	2.523	759.9	.3847	2.384	759.2	.3778	2.260	758.5	.3712	290
300	2.561	765.8	1.3926	2.421	765.2	1.3857	2.295	764.5	1.3791	300
320	2.637	777.7	.4081	2.493	777.1	.4012	2.364	776.5	.3947	320
340	2.713	789.6	.4231	2.565	789.0	.4163	2.432	788.5	.4099	340

TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.

[V=volume in ft.<sup>3</sup>/lb.; H=heat content in Btu./lb.; S=entropy in Btu./lb. °F.]

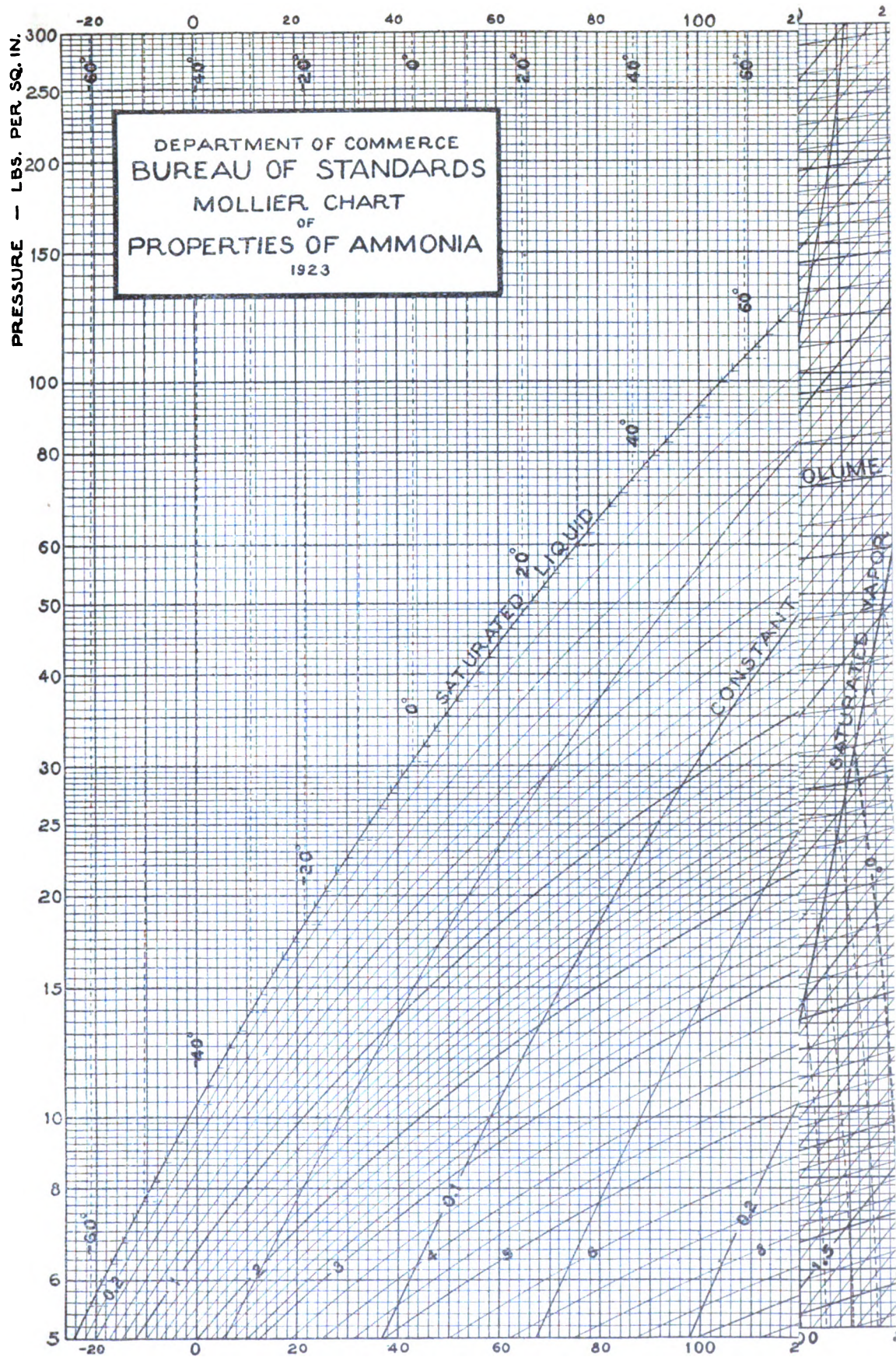
Temp. °C.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)									Temp. °F.
	200 <i>96.34°</i>			210 <i>99.45°</i>			220 <i>102.48°</i>			
	V	H	S	V	H	S	V	H	S	
<i>Sat.</i>	<i>1.502</i>	<i>632.7</i>	<i>1.1756</i>	<i>1.431</i>	<i>633.0</i>	<i>1.1715</i>	<i>1.367</i>	<i>633.2</i>	<i>1.1671</i>	<i>Sat.</i>
110	1.567	643.4	1.1947	1.480	641.5	1.1863	1.400	639.4	1.1781	110
120	1.612	650.9	.2077	1.524	649.1	.1996	1.443	647.3	.1917	120
130	1.656	658.1	.2200	1.566	656.4	.2121	1.485	654.8	.2045	130
140	1.698	665.0	.2317	1.608	663.5	.2240	1.525	662.0	.2167	140
150	1.740	671.8	1.2429	1.648	670.4	1.2354	1.564	669.0	1.2281	150
160	1.780	678.4	.2537	1.687	677.1	.2464	1.601	675.8	.2394	160
170	1.820	684.9	.2641	1.725	683.7	.2569	1.638	682.5	.2501	170
180	1.859	691.3	.2742	1.762	690.2	.2672	1.675	689.1	.2604	180
190	1.897	697.7	.2840	1.799	696.6	.2771	1.710	695.5	.2704	190
200	1.935	703.9	1.2935	1.836	702.9	1.2867	1.745	701.9	1.2801	200
210	1.972	710.1	.3029	1.872	709.2	.2961	1.780	708.2	.2896	210
220	2.009	716.3	.3120	1.907	715.3	.3053	1.814	714.4	.2989	220
230	2.046	722.4	.3209	1.942	721.5	.3143	1.848	720.6	.3079	230
240	2.082	728.4	.3296	1.977	727.6	.3231	1.881	726.8	.3168	240
250	2.118	734.5	1.3382	2.011	733.7	1.3317	1.914	732.9	1.3255	250
260	2.154	740.5	.3467	2.046	739.8	.3402	1.947	739.0	.3340	260
270	2.189	746.5	.3550	2.080	745.8	.3486	1.980	745.1	.3424	270
280	2.225	752.5	.3631	2.113	751.8	.3568	2.012	751.1	.3507	280
290	2.260	758.5	.3712	2.147	757.9	.3649	2.044	757.2	.3588	290
300	2.295	764.5	1.3791	2.180	763.9	1.3728	2.076	763.2	1.3668	300
320	2.364	776.5	.3947	2.246	775.9	.3884	2.140	775.3	.3825	320
340	2.432	788.5	.4099	2.312	787.9	.4037	2.203	787.4	.3978	340
360	2.500	800.5	.4247	2.377	800.0	.4186	2.265	799.5	.4127	360
380	2.568	812.5	.4392	2.442	812.0	.4331	2.327	811.6	.4273	380
	250 <i>110.80°</i>			260 <i>113.48°</i>			270 <i>115.97°</i>			
<i>Sat.</i>	<i>1.202</i>	<i>633.8</i>	<i>1.1555</i>	<i>1.155</i>	<i>633.9</i>	<i>1.1518</i>	<i>1.118</i>	<i>633.9</i>	<i>1.1483</i>	<i>Sat.</i>
120	1.240	641.5	1.1690	1.182	639.5	1.1617	1.128	637.5	1.1544	120
130	1.278	649.6	.1827	1.220	647.8	.1757	1.166	645.9	.1689	130
140	1.316	657.2	.1956	1.257	655.6	.1889	1.202	653.9	.1823	140
150	1.352	664.6	1.2078	1.292	663.1	1.2014	1.236	661.6	1.1950	150
160	1.386	671.8	.2195	1.326	670.4	.2132	1.269	669.0	.2071	160
170	1.420	678.7	.2306	1.359	677.5	.2245	1.302	676.2	.2185	170
180	1.453	685.5	.2414	1.391	684.4	.2354	1.333	683.2	.2296	180
190	1.486	692.2	.2517	1.422	691.1	.2458	1.364	690.0	.2401	190
200	1.518	698.8	1.2617	1.453	697.7	1.2560	1.394	696.7	1.2504	200
210	1.549	705.3	.2715	1.484	704.3	.2658	1.423	703.3	.2603	210
220	1.580	711.7	.2810	1.514	710.7	.2754	1.452	709.8	.2700	220
230	1.610	718.0	.2902	1.543	717.1	.2847	1.481	716.2	.2794	230
240	1.640	724.3	.2993	1.572	723.4	.2938	1.509	722.6	.2885	240
250	1.670	730.5	1.3081	1.601	729.7	1.3027	1.537	728.9	1.2975	250
260	1.699	736.7	.3168	1.630	736.0	.3115	1.565	735.2	.3063	260
270	1.729	742.9	.3253	1.658	742.2	.3200	1.592	741.4	.3149	270
280	1.758	749.1	.3337	1.686	748.4	.3285	1.620	747.7	.3234	280
290	1.786	755.2	.3420	1.714	754.5	.3367	1.646	753.9	.3317	290
300	1.815	761.3	1.3501	1.741	760.7	1.3449	1.673	760.0	1.3399	300
320	1.872	773.5	.3659	1.796	772.9	.3608	1.726	772.3	.3559	320
340	1.928	785.7	.3814	1.850	785.2	.3763	1.778	784.6	.3714	340
360	1.983	797.9	.3964	1.904	797.4	.3914	1.830	796.9	.3866	360
380	2.038	810.1	.4111	1.957	809.6	.4062	1.881	809.1	.4014	380
400	2.093	822.3	1.4255	2.009	821.9	1.4206	1.932	821.4	1.4158	400

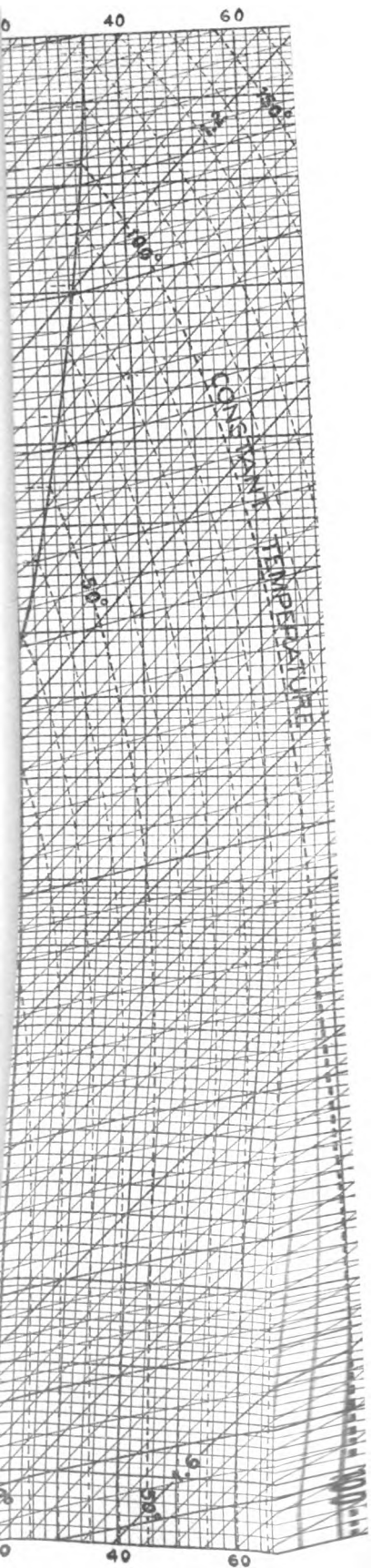
TABLE 5.—Properties of Superheated Ammonia Vapor—Continued.

[V=volume in ft.<sup>3</sup>/lb.; H=heat content in Btu./lb.; S=entropy in Btu./lb. °F.]

Temp. °F.	Absolute pressure in lbs./in. <sup>2</sup> (Saturation temperature in italics.)									Temp. °F.
	230 <i>105.30°</i>			240 <i>108.09°</i>			250 <i>110.80°</i>			
	V	H	S	V	H	S	V	H	S	
<i>Sat.</i>	<i>1.307</i>	<i>633.4</i>	<i>1.1631</i>	<i>1.283</i>	<i>633.3</i>	<i>1.1599</i>	<i>1.202</i>	<i>633.3</i>	<i>1.1555</i>	<i>Sat.</i>
110	1.328	637.4	1.1700	1.261	635.3	1.1621	1.240	641.5	1.1690	110
120	1.370	645.4	1.1840	1.302	643.5	1.1764	1.278	649.6	1.1827	120
130	1.410	653.1	1.1971	1.342	651.3	1.1898	1.316	657.2	1.1956	130
140	1.449	660.4	1.2095	1.380	658.8	1.2025	1.352	664.6	1.2078	140
150	1.487	667.6	1.2213	1.416	666.1	1.2145	1.386	671.8	1.2195	150
160	1.524	674.5	1.2325	1.452	673.1	1.2259	1.420	678.7	1.2306	160
170	1.559	681.3	1.2434	1.487	680.0	1.2369	1.453	685.5	1.2414	170
180	1.594	687.9	1.2538	1.521	686.7	1.2475	1.486	692.2	1.2517	180
190	1.629	694.4	1.2640	1.554	693.3	1.2577	1.518	698.8	1.2617	190
200	1.663	700.9	1.2738	1.587	699.8	1.2677	1.549	705.3	1.2715	200
210	1.696	707.2	1.2834	1.619	706.2	1.2773	1.580	711.7	1.2810	210
220	1.729	713.5	1.2927	1.651	712.6	1.2867	1.610	718.0	1.2902	220
230	1.762	719.8	1.3018	1.683	718.9	1.2959	1.640	724.3	1.2993	230
240	1.794	726.0	1.3107	1.714	725.1	1.3049	1.670	730.5	1.3081	240
250	1.826	732.1	1.3195	1.745	731.3	1.3137	1.699	736.7	1.3168	250
260	1.857	738.3	1.3281	1.775	737.5	1.3224	1.729	742.9	1.3253	260
270	1.889	744.4	1.3365	1.805	743.6	1.3308	1.758	749.1	1.3337	270
280	1.920	750.5	1.3448	1.835	749.8	1.3392	1.786	755.2	1.3420	280
290	1.951	756.5	1.3530	1.865	755.9	1.3474	1.815	761.3	1.3501	290
300	1.982	762.6	1.3610	1.895	762.0	1.3554	1.842	767.3	1.3589	300
320	2.043	774.7	1.3767	1.954	774.1	1.3712	1.872	773.5	1.3659	320
340	2.103	786.8	1.3921	2.012	786.3	1.3866	1.902	779.7	1.3814	340
360	2.163	798.9	1.4070	2.069	798.4	1.4016	1.932	785.9	1.3964	360
380	2.222	811.1	1.4217	2.126	810.6	1.4163	1.962	792.1	1.4111	380
	280 <i>118.46°</i>			290 <i>120.86°</i>			300 <i>123.81°</i>			
<i>Sat.</i>	<i>1.078</i>	<i>634.0</i>	<i>1.1449</i>	<i>1.034</i>	<i>634.0</i>	<i>1.1415</i>	<i>0.999</i>	<i>634.0</i>	<i>1.1383</i>	<i>Sat.</i>
120	1.078	635.4	1.1473	1.068	642.1	1.1554	1.023	640.1	1.1487	120
130	1.115	644.0	1.1621	1.103	650.5	1.1695	1.058	648.7	1.1632	130
140	1.151	652.2	1.1759	1.136	658.5	1.1827	1.091	656.9	1.1767	140
150	1.184	660.1	1.1888	1.168	666.1	1.1952	1.123	664.7	1.1894	150
160	1.217	667.6	1.2011	1.199	673.5	1.2070	1.153	672.2	1.2014	160
170	1.249	674.9	1.2127	1.229	680.7	1.2183	1.183	679.5	1.2129	170
180	1.279	681.9	1.2239	1.259	687.7	1.2292	1.211	686.5	1.2239	180
190	1.309	688.9	1.2346	1.287	694.6	1.2396	1.239	693.5	1.2344	190
200	1.339	695.6	1.2449	1.315	701.3	1.2497	1.267	700.3	1.2447	200
210	1.367	702.3	1.2550	1.343	707.9	1.2596	1.294	706.9	1.2546	210
220	1.396	708.8	1.2647	1.370	714.4	1.2691	1.320	713.5	1.2642	220
230	1.424	715.3	1.2742	1.397	720.9	1.2784	1.346	720.0	1.2736	230
240	1.451	721.8	1.2834	1.423	727.3	1.2875	1.372	726.5	1.2827	240
250	1.478	728.1	1.2924	1.449	733.7	1.2964	1.397	732.9	1.2917	250
260	1.505	734.4	1.3013	1.475	740.0	1.3051	1.422	739.2	1.3004	260
270	1.532	740.7	1.3099	1.501	746.3	1.3137	1.447	745.5	1.3090	270
280	1.558	747.0	1.3184	1.526	752.5	1.3221	1.472	751.8	1.3175	280
290	1.584	753.2	1.3268	1.551	758.7	1.3303	1.496	758.1	1.3257	290
300	1.610	759.4	1.3350	1.601	771.1	1.3464	1.544	770.5	1.3419	300
320	1.661	771.7	1.3511	1.650	783.5	1.3621	1.592	782.9	1.3576	320
340	1.712	784.0	1.3667	1.698	795.8	1.3773	1.639	795.3	1.3729	340
360	1.762	796.3	1.3819	1.747	808.2	1.3922	1.686	807.7	1.3878	360
380	1.811	808.7	1.3967	1.794	820.5	1.4067	1.732	820.1	1.4024	380
400	1.861	821.0	1.4112							400

**ADDITIONAL COPIES** of the Mollier Chart, printed from the same plate on a sheet 10½ by 25 inches, may be procured from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents per copy. (Ask for Bureau of Standards Miscellaneous Publications, No. 52.)





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*Sample*

*Figures*

## DEPARTMENT OF COMMERCE.

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BUREAU OF STANDARDS.

GEORGE K. BURGESS, Director.

### CIRCULAR OF THE BUREAU OF STANDARDS.

No. 143.

[Issued June 25, 1922.]

## RECOMMENDED SPECIFICATION FOR QUICKLIME FOR USE IN CAUSTICIZING.

This is the third of a series of specifications for the lime used in various chemical industries. To assist in the development of these specifications the bureau has called together an Interdepartmental Conference on Chemical Lime, composed of representatives of the Geological Survey and Bureau of Mines of the Interior Department; the Bureau of Soils, Bureau of Chemistry, Forest Service, and Fixed Nitrogen Research Laboratory of the Department of Agriculture; and the Chemical Warfare Service of the War Department. The present specification, based on a draft originally prepared by R. C. Wells, physical chemist, U. S. Geological Survey, has been unanimously approved by the above conference. It has the approval, with reservation, of the National Lime Association, and has been approved by the Technical Association of the Pulp and Paper Industry, representing the largest users of this kind of lime.

### ABSTRACT.

A brief description of the way in which lime is used in causticizing is followed by a general statement as to the quality of lime required.

The standard of quality for lime for this purpose is set at 85 per cent available lime. Any shipment containing less than 70 per cent available lime, or more than 3 per cent magnesia should be rejected as uneconomical to use.

Complete directions for sampling, testing, and retesting are included.

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## 1. GENERAL.

(a) DEFINITION OF QUICKLIME.—Quicklime is a product resulting from the calcination of limestone and consists essentially of calcium oxide, or of calcium and magnesium oxides. It will slake when water is added to it, and this slaking is accompanied by an evolution of heat and an increase in volume.

(b) USE OF LIME IN CAUSTICIZING.—Lime is added to solutions containing alkali carbonates for the purpose of forming the corresponding hydroxides, or caustic alkalies. These remain in solution, while calcium carbonate is precipitated. The solution and precipitate are separated; the solution is concentrated by evaporation to the extent desired for the object in view, and the calcium carbonate sludge is either converted into lime or discarded.

(c) QUALITY.—The impurities ordinarily found in lime, as well as underburned and overburned lime, retard the slaking process. They also increase the volume of the sludge, which then either requires more time in washing or carries off more inclosed caustic alkali. Magnesium compounds do not settle either quickly or well in the solution of caustic. The presence of any impurities thus introduces delays which reduce the efficiency of the equipment.

(d) PACKING.—Quicklime is shipped either in bulk in carloads lots, or in barrels each holding 180 or 280 pounds net.

## 2. REQUIREMENTS.

(a) COMPOSITION.—The standard of composition for quicklime for use in causticizing shall be a content of 85 per cent of available lime.<sup>1</sup> Lime containing more than 3 per cent magaesia or less

<sup>1</sup> It is recommended that a bonus or a penalty of 1¼ per cent of the contract price be added to or deducted from the payment for each 1 per cent of available lime above or below the standard 85 per cent. It may be desirable in some cases to make other constituents than lime subject to bonus or penalty provisions.

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than 70 per cent of available lime shall be rejected as uneconomical to use. All percentages enumerated herein are based on the sample as received at the laboratory.

(b) **MARKING.**—Each carload of material or fraction thereof shall be legibly marked with the names of the consignor and consignee and with some means of identifying the particular contract on which the shipment is made. This information is in addition to that required by the Federal lime barrel law.

(c) **RETESTING.**—Notice of the rejection of a shipment based on these specifications must be in the hands of the consignor within 10 days after the receipt of the shipment at the point of destination. If the consignor desires a retest, he shall notify the consignee within 5 days of receipt of the notice of rejection. The consignee shall provide all reasonable facilities to permit the consignor to resample the material. The retest shall be at the expense of the consignor.

### 3. SAMPLING AND TESTING.

(a) **SAMPLING.**—The purchaser will bear all expense of sampling and testing. When quicklime is shipped in bulk, the sample shall be so taken that it will represent an average of all parts of the shipment from top to bottom, and shall not contain a disproportionate share of the top and bottom layers, which are most subject to changes. The sample shall consist of 1 shovelful for each 3 tons of material, but not less than 10 shovelfuls taken from different parts of the shipment. The total sample taken shall weigh at least 100 pounds, and shall be crushed to pass a 1-inch ring, mixed thoroughly, and "quartered" to provide a 15-pound sample for the laboratory. In case a shipment consists of more than one car, a separate sample shall be taken from each car.

When quicklime is shipped in barrels, at least 3 per cent of the number of barrels shall be sampled. They shall be taken from various parts of the shipment, dumped, mixed, and sampled as specified in the above paragraph.

When sampling quicklime, it is essential that the operation be conducted as expeditiously as possible, in order to avoid undue exposure of the material to the air. The sample to be sent to the laboratory shall immediately be placed in an air-tight container, in which the unused portion shall be stored until the shipment has been finally accepted or rejected by the purchaser.

The sample may be taken either at the point of shipment or at the point of destination, as agreed upon by the contracting parties.

(b) TESTING.—Details regarding the complete analysis of lime are given in other papers of this series and in Bulletin 700 of the U. S. Geological Survey.

*Available lime.*—1. To 1.4 g of the carefully prepared and finely ground (passing a No. 100 sieve) lime in a 400-cc beaker add 200 cc of hot water, cover, heat carefully, and then boil for three minutes.

2. Cool, wash down cover, add two drops of phenolphthalein and titrate with normal hydrochloric acid, adding the acid dropwise as rapidly as possible, stirring vigorously to avoid local excess of acid. When white spots appear, retard the rate of addition of acid somewhat, but continue until the pink color fades out throughout the solution for a second or two. Note the reading and ignore the return of color.

3. Repeat the procedure of paragraph 1 above, using (instead of a beaker) a liter graduated flask carrying a one-hole stopper fitted with a short glass tube drawn out to a point. Cool, add slowly 5 cc less acid than before, stirring vigorously. Call the number of cc used "A." Grind up any small lumps with a glass rod slightly flattened at one end, dilute to the mark with freshly boiled distilled water, stopper, mix thoroughly for four or five minutes, and let settle for half an hour.

4. Pipette off a 200-cc portion, add phenolphthalein and titrate slowly with half-normal hydrochloric acid until colorless on standing one minute. Call this additional number of cc "B." Then, percentage of available lime =  $2A + 5B$ .

*Magnesia.*—The magnesia determination is made after removing silica, iron oxide, alumina, and lime. Ignite 1 g, or if the magnesium content is high, 0.5 g, of the sample strongly in a platinum crucible for 15 minutes. When cool, moisten the residue and dissolve it in 1 : 1 hydrochloric acid, evaporate to dryness on the steam bath, take up in 5 cc of hydrochloric acid, add 50 cc of water, and filter off the silica. To the filtrate add 5 cc of hydrochloric acid, then make it slightly alkaline with ammonia, heat to boiling, and filter off the oxides of iron and aluminum. Acidify the filtrate slightly, heat to boiling, add ammonium oxalate slowly to excess, then ammonia slowly until in slight excess. After the precipitate has settled for one to two hours filter and wash with an ammoniacal ammonium oxalate solution. Reserve the filtrate. Ignite the precipitate. When cool moisten it, dissolve in hydrochloric acid, and reprecipitate. Filter off the calcium oxalate, washing with ammoniacal ammonium oxalate solution. Discard the precipitate,

combine the filtrate with the first one, slightly acidify with hydrochloric acid, and add an excess of microcosmic salt. Then slowly add ammonia until a crystalline precipitate forms or the solution is alkaline. Finally add one-fifth of the volume of ammonia water in excess. After the precipitate has fully formed, preferably by standing overnight, filter and wash with dilute ammonia water (5 per cent by volume). Dissolve the precipitate in a slight excess of hydrochloric acid, add one or two drops of phosphate solution, and reprecipitate by adding ammonia while stirring, finally adding 2 or 3 cc of ammonia in excess. Filter, wash with 5 per cent ammonia, and ignite to constant weight. Weight of magnesium pyrophosphate  $\times 0.3621$  = weight of magnesium oxide.

For rapid work the first precipitate of magnesium phosphate may be ignited, or it may be washed slightly with dilute ammonia, then with alcohol until free from ammonia, dried on the paper at 80° C. in a small beaker, dissolved in an excess of tenth-normal sulphuric acid, and titrated back with tenth-normal sodium hydroxide, using methyl orange as indicator (cc acid - cc alkali)  $\times 0.00201$  = grams magnesium oxide.

WASHINGTON, April 11, 1923.

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**DEPARTMENT OF COMMERCE****BUREAU OF STANDARDS.****GEORGE K. BURGESS, Director.**U.S.**CIRCULAR OF THE BUREAU OF STANDARDS.****No. 144.**

[JULY 6, 1923.]

**RECOMMENDED SPECIFICATION FOR LIMESTONE  
AND QUICKLIME FOR USE IN THE MANUFACTURE  
OF SULPHITE PULP.****ABSTRACT.**

Limestone or quicklime is used to prepare the cooking liquor in which wood is cooked to reduce it to paper pulp. It is customary to use a high calcium limestone when preparing liquor by the tower process or a high magnesian quicklime with the tank process, but other kinds of limestone or quicklime are being used. The specifications, therefore, cover high calcium and high magnesium limestone and quicklime on a basis of about 95 per cent purity.

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This is the fourth of a series of specifications for the lime used in various chemical industries. To assist in the development of these specifications, the bureau has called together an Interdepartmental Conference on Chemical Lime, composed of representatives of the Geological Survey and Bureau of Mines, of the Interior Department; the Bureau of Soils, Bureau of Chemistry, Forest Service, and Fixed Nitrogen Research Laboratory, of the Department of Agriculture; and the Chemical Warfare Service, of the War Department. The present specification, based on a draft originally prepared by F. A. Curtis, of the paper section, Bureau of Standards, has been unanimously approved by the above conference, by the National Lime Association, and by the Technical Association of the Pulp and Paper Industry.

## **I. GENERAL.**

### **1. MANUFACTURE OF SULPHITE PULP.**

(a) **OUTLINE OF PROCESS.**—The manufacture of pulp for paper making from wood by means of the sulphite process consists of the following operations: (1) Preparation of the wood, (2) preparation of the cooking liquor, (3) cooking of the wood, (4) washing and screening the pulp, (5) bleaching the pulp, and (6) preparation of the finished pulp for shipment.

The use of limestone and lime in this manufacturing process occurs in the preparation of the cooking liquor. This liquor is produced by the reaction between sulphur dioxide and limestone or lime, and the two absorption methods in common use are called the tower system and the tank system. The liquor is essentially a calcium or calcium and magnesium salt of sulphurous acid, and its function is to affect the noncellulose part of the wood in such a manner that, in the washing and bleaching process, nearly pure cellulose may be obtained.

(b) **KIND OF STONE AND LIME REQUIRED.**—There is some difference of opinion in this country as to the relative merits of high calcium and high magnesium stone and lime for use in the two absorption systems. The difference in practice in the various pulp mills does not seem to be based on accurate data.

### **2. LIMESTONE.**

(a) **DEFINITION.**—Limestone consists, essentially, of calcium carbonate or of calcium and magnesium carbonate, where the amount of the latter does not exceed 45.5 per cent.

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(b) **USE OF LIMESTONE IN THE TOWER SYSTEM.**—The tower type of absorption system consists of one or more towers varying in height from 20 to 150 feet and charged with limestone resting on gratings. A stream of water, with or without the addition of reclaimed liquor, trickles over this stone, while the sulphur dioxide enters at the bottom, rises, and acts upon the moist stone and is absorbed by the downward flowing film of water.

(c) **KIND OF STONE PREFERRED.**—In the tower system high calcium stone is desired, due principally to the fact that when high magnesium stone is used the calcium carbonate goes into solution first, causing the stone to crumble and leave a sludge. For this reason, in a tower system using high magnesium stone, it is customary to have the grates raised 40 to 50 feet, and they require frequent cleaning. One mill is using and recommends high magnesium stone. However, most of the mills are using high calcium stone, and, in fact, several are using marble having a calcium carbonate content of 98.5 per cent. It can not be said, however, that high magnesium stone can not be used in the tower system, but it is not the most common practice.

(d) **PACKING.**—Limestone is shipped in bulk in carload lots.

### 3. QUICKLIME.

(a) **DEFINITION.**—Quicklime is the product resulting from the calcination of limestone and consists, essentially, of calcium oxide or of calcium and magnesium oxides. It will slake when water is added to it, and this slaking is accompanied by an evolution of heat and an increase in volume.

(b) **USE OF LIME IN THE TANK SYSTEM.**—In the tank or milk of lime system the lime is in solution or suspension in a series of tanks, equipped with suitable agitators. The sulphur dioxide is forced or drawn through these tanks successively. The contents of the first tank are drawn off when the liquor has reached a certain strength (3.5 to 6 per cent total  $\text{SO}_2$ ), and the contents of the second and third tanks progress to the first and second tanks, respectively. The third tank is again charged with fresh milk of lime. In some cases the tanks are built on top of each other in the form of a tower, and the process may then be operated continuously.

(c) **KIND OF LIME PREFERRED.**—In the tank system a lime high in magnesium is desired, due to the fact that the magnesium salts are soluble, while the calcium salts are not so soluble and have a tendency to clog the system. But, due to variations in tank

systems, it is probable that a high calcium lime would give good results in certain instances.

(d) **PACKING.**—Quicklime is shipped either in bulk, in carload lots, or barrels holding 180 pounds net or 280 pounds net each.

## II. REQUIREMENTS.

### 1. QUALITY.

The quality of the stone or lime should be reasonably uniform, and in the case of the high magnesium stone or lime the proportions of magnesium and calcium should be kept as nearly constant as possible.

### 2. LIMESTONE.

(a) **COMPOSITION.**—In view of the fact that various systems may use different grades of stone or lime, the requirements of these specifications are so given that they will meet the conditions of the pulp mills in this country. The maximum and minimum quantities are given in the following table:

TABLE 1.—Composition of Limestone.

Ingredients.	High calcium stone.		High magnesium stone.	
	Maximum.	Minimum.	Maximum.	Minimum.
Calcium oxide.....		53.0		29.6
Magnesium oxide.....	1.5			17.9
Oxides of silicon, iron, and aluminum.....	1.5		1.5	
Organic matter.....	.5		.5	

(b) **IMPURITIES.**—The impurities present in a limestone must be evenly distributed throughout the mass and must not be concentrated in visible strata or nodules which would clog the grates. The stone shall contain no strata of an argillaceous or organic nature which might cause the pieces of limestone to split.

(c) **SIZE.**—Each piece of limestone shall be large enough so that it will be retained on a 3-inch ring, but small enough so that it can be lifted readily by one man.

(d) **DENSITY.**—Limestone shall be of such a density that a block of it will weigh not more than 180 nor less than 150 pounds per cubic foot.

3. QUICKLIME.<sup>1</sup>

TABLE 2.—Composition of Quicklime.

Ingredients.	High calcium lime.		High magnesium lime.	
	Maximum.	Minimum.	Maximum.	Minimum.
Calcium oxide.....		92.5		55.4
Magnesium oxide.....	2.5			39.6
Oxides of silicon, iron, and aluminum.....	3.0		3.0	

## 4. MARKING.

Each carload of material or fraction thereof shall be legibly marked with the names of the consignor and consignee and with some means of identifying the particular contract on which the shipment is made.

## 5. RETESTING.

Notice of the rejection of a shipment based on these specifications must be in the hands of the consignor within 10 days after the receipt of the shipment at the point of destination. If the consignor desires a retest he shall notify the consignee within five days of receipt of the notice of rejection. The consignee shall provide all reasonable facilities to permit the consignor to resample the material. This retest shall be at the expense of the consignor.

## III. SAMPLING AND TESTING.

## 1. SAMPLING.

The purchaser will bear all expense of sampling and testing. When limestone or quicklime is shipped in bulk, the sample shall be so taken that it will represent an average of all parts of the shipment from top to bottom and shall not contain disproportionate share of the top and bottom layers. The sample shall consist of 1 shovelful for each 3 tons of material, but not less than 10 shovelfuls taken from different parts of the shipment. The total sample

<sup>1</sup> The above requirements as to the composition of quicklime are based on the sample as received. If it is desired to use the nonvolatile basis, the figures should be changed to the following:

*Composition of quicklime on nonvolatile basis.*

Ingredients.	High calcium lime.		High magnesium lime.	
	Maximum.	Minimum.	Maximum.	Minimum.
Calcium oxide.....		94.3		56.5
Magnesium oxide.....	2.6			40.4
Oxides of silicon, iron, and aluminum.....	3.1		3.1	
Carbon dioxide.....	5.0		5.0	

taken shall weigh at least 100 pounds and shall be crushed to pass a 1-inch ring; mixed thoroughly, and "quartered" to provide a 15-pound sample. This 15-pound sample shall be crushed to pass a one-half inch ring, mixed thoroughly, and quartered to provide a 2-pound sample for the laboratory. In case a shipment consists of more than 1 car, a separate sample shall be taken from each car.

When quicklime is shipped in barrels, at least 3 per cent of the number of barrels shall be sampled. They shall be taken from various parts of the shipment, dumped, mixed, and sampled as specified in the above paragraph.

When sampling quicklime, it is essential that the operation be conducted as expeditiously as possible in order to avoid undue exposure of the material to the air. The sample to be sent to the laboratory shall immediately be placed in an air-tight container in which the unused portion shall be stored until the shipment has been finally accepted or rejected by the purchaser.

## 2. TESTING.

The following directions are a brief summary of the analytical methods which are recommended. For more complete information on this subject references should be made to *The Analysis of Silicate and Carbonate Rocks*, by W. F. Hillebrand, U. S. Geological Survey, Bulletin No. 700.

Blast 0.5 g of the sample for 15 minutes in a platinum crucible. Cool and transfer to an evaporating dish. Mix to a slurry with distilled water. Add 5 to 10 cc concentrated HCl. Heat gently until solution is complete, breaking up lumps if necessary. Evaporate to dryness on water bath. Add 5 to 10 cc concentrated HCl, and dilute with an equal volume of distilled water. Digest on water bath for 10 minutes. Filter and wash with hot water. Evaporate the filtrate to dryness. Dissolve in acid and water as before. Filter and wash with hot water. Ignite the two precipitates together and weigh as silica and insoluble matter.

Dilute the above filtrate to 250 cc. Add HCl, if necessary, to insure a total volume of 10 to 15 cc of this acid in this solution. Make alkaline with  $\text{NH}_4\text{OH}$ . Boil until odor of  $\text{NH}_3$  is barely noticeable. Filter and wash slightly with hot water. Dissolve the precipitate with hot dilute HCl and repeat the precipitation as before. Filter and wash thoroughly with hot water. Ignite and weigh as oxides of iron and aluminum.

To the filtrates from the above add a few drops of  $\text{NH}_4\text{OH}$  and bring to a boil. Add 25 cc of a saturated solution of  $(\text{NH}_4)_2\text{C}_2\text{O}_4$ . Continue boiling until the precipitate becomes granular. Let stand until precipitate settles clear. Filter and wash with boiling water. Ignite the precipitate, dissolve in dilute  $\text{HCl}$ , and dilute to 100 cc. Add excess of  $\text{NH}_4\text{OH}$  and boil. Filter out any insoluble matter, ignite and weigh, and add its weight to the oxides of iron and alumina found previously. To this filtrate add  $(\text{NH}_4)_2\text{C}_2\text{O}_4$ , proceeding as before. Filter and wash with boiling water. Ignite and blast to constant weight as calcium oxide.

Acidify the filtrates from the above with  $\text{HCl}$ . Evaporate to 150 cc. Add 10 cc of a saturated solution of  $\text{NaNH}_4\text{HPO}_4$ . Add  $\text{NH}_4\text{OH}$  drop by drop, with constant stirring, until the precipitate starts to form. Then add moderate excess of  $\text{NH}_4\text{OH}$ . Stir for several minutes. Let stand over night. Filter and dissolve the precipitate in hot dilute  $\text{HCl}$ . Dilute to 10 cc, add 1 cc of saturated solution of  $\text{NaNH}_4\text{HPO}_4$ , and precipitate as before. Filter and wash with an alkaline solution made by diluting  $\text{NH}_4\text{OH}$  until it contains about  $2\frac{1}{2}$  per cent  $\text{NH}_3$ , and then add a few drops of  $\text{HNO}_3$ . Ignite and weigh as  $\text{Mg}_2\text{P}_2\text{O}_7$ . Multiply this weight by 0.3621 to find the weight of  $\text{MgO}$ .

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**BUREAU OF STANDARDS**  
**George K. Burgess, Director**

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**CIRCULAR OF THE BUREAU OF STANDARDS, No. 145**

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**SUMMARY OF TECHNICAL METHODS  
FOR THE UTILIZATION OF MOLASSES**

**COLLATED FROM PATENT LITERATURE**

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**January 28, 1924**



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# SUMMARY OF TECHNICAL METHODS FOR THE UTILIZATION OF MOLASSES.

COLLATED FROM PATENT LITERATURE.

## ABSTRACT.

Economic conditions the world over have made it generally recognized that the future of the American beet-sugar industry is to a great extent dependent on the profitable utilization of the molasses produced. The latter contains numerous valuable substances which have never been successfully recovered outside of Germany. For many years that country has seen fit to veil its developments and discoveries and to maintain the strictest secrecy regarding the operation of its molasses plants. The scientific literature on the subject is practically barren, so far as the actual results achieved in Germany are concerned. In order to carry out the necessary experimental work for the American industry every possible source of information has been investigated. After a few clues were obtained the United States Patent Office literature was searched and eventually over 1,000 German patents on molasses utilization and associated subjects were uncovered. The difficulty in locating these patents was due to the fact that they are not listed under sugar or molasses or subjects that were known to the bureau's investigators. The value of the information contained in many of these patents was so apparent and the necessity for knowledge of their contents was so obvious that the present résumé of the more important patents on the recovery of the nonsugars has been compiled.

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## I. INTRODUCTION.

(a) ECONOMIC CONDITIONS.—Economic conditions the world over, especially in the older and basic industries, have made it imperative that each industry utilize its raw materials to the fullest possible degree. This fact is particularly applicable to the American beet-sugar industry, and the necessity for a more efficient utilization of the beet molasses produced in the United States has long been recognized. Perhaps no other commercial commodity produced on a large scale has had as wide a variation in actual value. At times it has been a valuable asset to the companies producing it, and at times it has been an actual liability. It contains numerous valuable substances, and probably all the American beet-sugar producing companies have at some time given serious consideration to the development of economically successful methods for the recovery of these substances. Sufficient has been accomplished in this direction to prove that the problems involved are highly scientific and technical, and that the information desired can be secured only at the expense of long-continued research in specially designed laboratories.

(b) FOREIGN PRACTICE.—It has become generally recognized that the future of the American beet-sugar industry is in no small degree dependent on the profitable recovery of these by-products. Naturally, it is to be expected that the greatest development in this field should be attained by European beet-sugar companies where the industry was first developed. Prior to 1914 approximately one-half the world's sugar supply was produced from sugar beets, and, with the economic conditions

which have long prevailed in Europe, it is logical to expect that all the resources of modern science would have been utilized long ago to develop methods of recovery of the valuable by-products known to exist in such a large-scale production commodity as beet molasses. Much valuable research work has been done to that end in various interested countries, particularly France and Germany. It is in the latter country, however, judging from all available information, that great success has been attained. Four beet-sugar utilization plants were in operation in that country until some time between 1914 and 1918, when two of them were destroyed or converted to other purposes made necessary by the stress of war. Owing to the necessity of harvesting the sugar beet and recovering the sugar stored in it within a comparatively short time, it is impracticable to operate beet-sugar plants the entire year. The discovery of scientific methods of recovering the by-products made it possible to design the molasses-utilization plants to operate 12 months in the year. The great economy in operation which results is evident. The most noted of the four German plants is known as the Dessau plant, located in the city of Dessau.

Unfortunately for the world in general, the German beet industry has seen fit to veil its developments and discoveries in this field and to maintain the strictest secrecy regarding the operation of its plants. The scientific literature of the beet-sugar industry is practically barren so far as the actual results achieved in Germany are concerned. In the Bureau of Standards' efforts to collect existing information recourse was had to the U. S. Patent Office files in a search which led eventually to the uncovering of over 1,000 German patents on molasses utilization and associated subjects. The value of the information contained in many of these patents was so apparent, and the necessity for a knowledge of their contents was so obvious, especially in view of carrying out experimental work on American beet molasses, that the necessity for a complete patent survey was at once evident.

(c) SCOPE OF PATENT SEARCH.—A search has been carried on through the files of the patents of the United States, Great Britain, Germany, and France as found at the United States Patent Office in Washington, supplemented by references to and abstracts of patents found in the current literature. Considerable difficulty was experienced in making the search as comprehensive as possible because of the large number of classifications it was necessary to cover, especially in the German files, in order to locate not only

the most direct but the related patents concerned. It must be kept in mind that under the present systems of classification in vogue in the various countries it is impossible to choose only those patents which bear directly upon the desired subject. Neither is it possible to know which, by virtue of their titles alone or even their texts, are connected with that subject while appearing in an entirely different section of the patent classification. There remains also the fact that in many cases, contrary to the spirit of the patent laws, the titles and texts of the patents are so framed as to deliberately camouflage the nature and purpose of the process described. These conditions make it exceedingly difficult to select, without fail, all patents connected with a given problem and make it appear possible that some may have been overlooked which might profitably have been included. In presenting the following survey, therefore, no claim is made as to its completeness, but we simply state that the patents listed include all those which seemed to bear directly on the problem at hand.

(d) METHODS OF UTILIZING WASTE MOLASSES.—At the beginning of the search into the problem of the utilization of waste molasses, it is necessary to define the scope of the field to be covered. Waste molasses has found many uses, more or less practical. For instance, we find it being used as a fertilizer, a cattle feed, a source of alcohol, a medium for the production of yeast, a fuel, a filler in many manufactured products, and, in Germany, a source of potash and various valuable organic and inorganic chemicals. It would have proven very difficult to have covered adequately the patents in connection with all these various uses, and it was, therefore, necessary to limit the scope of the investigation in order to utilize the limited time to the greatest advantage.

(e) BASIS OF PATENT SURVEY.—Certain assumptions were made as to the nature of molasses and the practical forms of utilization as applied to the conditions in the United States. In the first place, greatest stress was laid on the discard molasses and waste water from the beet-sugar industry. Since the molasses from this source is not suitable for table use, it must be utilized in other ways. It was assumed, moreover, that in the modern sugar house the maximum quantity of available sucrose is extracted from the molasses by a suitable saccharate process, such as Steffen's process. This naturally eliminates from the discussion all consideration of the various saccharate processes, a subject which is of great importance and which we expect to discuss in a later publication. The residue left after the application of a saccharate process is a

waste water which contains all the nonsugars, consisting chiefly of inorganic salts of potassium and sodium and various organic nitrogenous bodies. In applying the Steffen cold saccharate process in most sections of the beet-sugar area of the country it has been found necessary to discard a portion of the molasses without desugarizing in order to eliminate from the extraction system certain harmful impurities which accumulate by recirculation. This discard molasses, of course, carries the same kinds of nonsugars, and, in addition, a relatively much larger amount of sugar.

The use of molasses as a source of alcohol and yeast is quite well known and generally practiced, but the erection of a plant for this purpose is expensive. In European countries beet sugar has long been the basic raw material for much of the alcohol produced. In the United States, however, grains as well as molasses have been utilized for the production of a considerable quantity of alcohol. More recently the marked decline in the price of molasses has resulted in its greatly increased use for this purpose. Recently there have been promising developments in the manufacture and use of alcohol as a motor fuel. Anhydrous ethyl alcohol is being produced in considerable quantities. Recent tests at this bureau have shown that a motor fuel consisting of 30 per cent of this material and 70 per cent gasoline gives results superior to gasoline. It is believed that the recent accomplishment of producing anhydrous ethyl alcohol in large quantities at a cost not greatly in excess of that of gasoline will prove most significant in the solution of the motor-fuel problem. Having utilized the discard molasses in this manner, however, we should still have to dispose of the valuable nonsugars now contained in the two residual liquors; first, the saccharate waste water mentioned above, and, second, the distillery slops or vinasses as they are called. The problem of the recovery of these substances in economically valuable forms again presents itself, whether the sugar of the molasses is recovered by a saccharate process or is converted to alcohol and yeast.

Of the other uses mentioned, disposal of the molasses as a fertilizer, a feed, or as a filler in various industrial products, presents a limited outlet and a poor financial return, although these methods serve their purpose in the agricultural economy.

The final consideration in any case in deciding upon the most practical plan for the utilization of waste molasses must hinge upon the economic or financial aspects of the problem. These facts naturally lead us to a consideration of the methods of recov-

ering the organic and inorganic values left in Steffen or other saccharate waste water or distillery slop as being the most economically feasible. It is upon this basis, therefore, that the present investigation is being conducted. The various assumptions on which the following patent survey is based may be stated as follows: (1) That the greatest need is for some method of utilization of the discard molasses and waste water of the beet-sugar industry; (2) that the maximum amount of molasses has been treated by the Steffen or other saccharate process to recover the maximum amount of sugar; (3) that the recovery of the organic and inorganic values in the waste water presents a hopeful outlook; and (4) that since methods of utilization have proven successful in other beet-sugar countries, such as Germany, some similar or analogous process might well be developed as an aid to the beet-sugar industry in the United States.

(f) COMPOUNDS FOUND IN WASTE MOLASSES.—Through the work of various investigators, chiefly in France and Germany, the nature of the various compounds to be found in beet-sugar waste waters has been made known. Among the possible products from beet molasses, exclusive of the sugar which may be almost entirely removed by means of saccharate processes, are the following: Methylamines, ammonia or ammonium sulphate, sodium or potassium cyanides, nitrogen bodies, such as betaine and glutaminic acid, alkali salts ( $K_2CO_3$ ,  $Na_2CO_3$ ,  $K_2SO_4$ ), vegetable carbon and tar, and various minor products, such as methyl alcohol, glycerin, organic acids, and esters. These latter have received considerable attention in the patent literature because of their production from distillery slop or vinasses. In arranging the results of our patent search, the patents have been grouped according to the chief product of the process described. These groups, in most cases, have been subdivided into smaller groups of a closely related nature, in order that the development of any one phase of the art might be more readily followed. No importance should be attached to this arrangement beyond affording a key by which to classify the patents. A chronological scheme of listing has been used throughout, except in such cases where the work of one patentee over a short period can be more easily observed by grouping together.

In addition to those patents bearing directly on the subject of the patent group, others have been included which seem to offer suggestive chemical information as to properties and reactions, as well as methods of preparation from similar sources, as, for

instance, the obtaining of various by-products from peat, animal waste, and other industrial wastes aside from those of the beet-sugar industry.

## II. PATENT OUTLINE AND SUMMARY.

GROUP 1.—AMINES.—Processes for producing methylamines from waste water. The patents indicate that little attention has been given to the preparation of amines as such from waste water or molasses. Methods for the preparation from other sources and the separation of the three methylamines are of interest from the research point of view.

GROUP 2.—AMMONIA.—(a) Production of ammonia directly from waste water, discard molasses, or other sugar wastes. (b) Production of ammonia from other industrial wastes. (c) Separation of the ammonia from processes of distillation or incineration. Means of absorbing, fixing, or purifying ammonia are so generally known in connection with the by-product coal industry that it was deemed inadvisable to make any attempt to cover this angle of the process completely. (d) Further processes for the production of ammonium salts from the constituents of the gases of dry distillation.

The principles used in the production of ammonia from waste water or molasses are included in a few well-defined methods: (1) Heating the waste water with an excess of alkali in any suitable container, said alkali sometimes being obtained from the waste-water ash. (2) Passing the gases from the dry distillation of waste water in contact with heated basic materials, such as lime, clays, bauxite, aluminates, or mixtures of waste-water ash and aluminates, which are subsequently treated for the recovery of the alkalies, alumina, etc. Various methods of using briquetted aluminates as a contact mass are described. (3) Calcining the waste water in contact with coke and steam to increase the yield of ammonia. (4) Ammonium salts are obtained directly by heating with acids, either with or without treatment with ferments.

Methods for obtaining ammonia from other industrial wastes are very similar to those noted above.

Under special conditions it is possible to prepare ammonium carbonate from the ammonia and carbon dioxide produced in the gases from the dry distillation of waste water.

GROUP 3.—APPARATUS.—Types of ovens, retorts, and miscellaneous equipment for all groups are described. In many cases

the descriptions of the process and the apparatus used are inseparable, and these have been introduced under their proper group classifications. Inasmuch as it is practically impossible to describe adequately a given type of apparatus without a diagram, illustrations of certain typical forms are introduced to simplify the description. The various types of apparatus are subdivided as follows: (a) Apparatus for incinerating and calcining waste water; (b) apparatus for evaporating and concentrating waste water; (c) apparatus for recovering ammonia from waste waters; and (d) apparatus for recovery of potash.

The development of retorts for dry distillation has been in the general direction of either rotating drums with stationary scrapers, or stationary retorts containing screw conveyors or other means of agitating and moving the incinerating mass. Many suggested pieces of equipment are highly complicated and could not be adequately reproduced, aside from the consideration of their practical utility.

GROUP 4.—CYANIDES.—In this group it was found necessary to limit the number of related patents to a small fraction of those actually gathered from the patent literature. The chemical principles entering into the production of cyanides by various high temperature and catalytic methods are so closely connected with those involved in their production from waste water that it proved difficult to limit the number included in the following lists. In general, however, where a patent was taken out on a related subject and it was known that the patentee was active in the field of our interest, such a patent was considered to have sufficient connection to warrant its inclusion.

The production of cyanides has been arranged in the following subgroups: (a) Production of cyanides from waste water direct; (b) production of cyanides from amines by special processes; (c) production of cyanides from various gas mixtures; (d) recovery of hydrocyanic acid from gas mixtures, and (e) preparation of cyanides in marketable form.

The present methods for the preparation of cyanides from waste water are developments of the original process of Ortlieb and Mueller <sup>1</sup> in the use of some type of superheater through which the gases from the dry distillation are passed either directly or after the separation of the cyanizable and noncyanizable constituents. Reichardt and Bueb patented the first application of this principle, using a checkerwork of fire brick heated to a red

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<sup>1</sup> Ger. 9409, Aktien Gesellschaft Croix (subgroup b).

or white heat as a cyanizing chamber. Subsequent patents have changed the form of the superheater to tubes made of quartz, zirconia, and other acidic materials.

One or all of the amines are also used in other ways than that described by Ortlieb and Mueller for producing cyanides, as in the process for passing the vaporized amine into molten sodium to produce the alkali cyanide directly.

By the use of catalysts, certain of the gases produced in the dry distillation of waste water may be made to combine to form hydrocyanic acid.

GROUP 5.—NITROGENOUS NONSUGARS.—Patents not previously listed under amines, ammonia, or cyanides, applying to nitrogenous compounds, such as betaine and glutaminic acid, are collected under the following groups: (a) Betaine and glutaminic acid from waste water and molasses, and (b) betaine prepared from other sources.

The methods for preparing betaine and glutaminic acid from waste water and molasses are, in general, variations of the treatment of those materials with either gaseous or aqueous hydrochloric acid and alcohol.

GROUP 6.—POTASH AND ALKALI SALTS.—Only those patents bearing directly on the waste-water problem have been taken for this survey. In the German files alone, there were innumerable related patents, dealing with alkali-salt systems with interesting chemical reactions and separations, which it was necessary to exclude.

The recovery of potash and alkali salts from the waste-water ash is accomplished by two general methods: (1) Evaporating, igniting, or calcining the waste water and leaching the resulting product in various ways to separate the potassium and sodium compounds. (2) Precipitation of the potash either with hydrofluosilicic acid or perchlorates.

Another form of utilization, developed to a considerable extent in America during the late war, is found in the direct use of the ash as a fertilizer.

GROUP 7.—RECOVERY OF MISCELLANEOUS PRODUCTS FROM WASTE WATER, MOLASSES, DISTILLERY SLOP, ETC.—This group includes all other products not previously mentioned, and is arranged under the following headings: (a) Glycerine, fatty acids, esters, etc.; (b) fertilizers, feed, etc.; (c) dyeing and mordanting materials; and (d) miscellaneous products—alkalies, phosphates, etc.

Glycerine and fatty acids are obtained from waste water by treatment of the dried residue with solvents, such as alcohol and acetone, or by fractional distillation under partial vacuum. The various specifications show slight changes from this procedure.

An interesting side-light on the use of waste water is as an agent in the dyeing and treating of wool, where the organic acids, particularly betaine acid, are the active reagents. In combination with ammonium molybdate, certain dyes may be obtained after treatment with sulphuric acid and alcohol which vary in color from light green to dark blue.

### III. PATENT SYSTEMS OF VARIOUS COUNTRIES.

For those not familiar with the patent systems of the various countries the following information is given:

**UNITED STATES.**—Patents numbered consecutively from the beginning. Dates given: (1) Application, (2) issue or patenting.

**GREAT BRITAIN.**—Patents numbered consecutively in each year, a new series starting with each succeeding year until 1916, when a change was made to the system used in the United States. Previous to that time, therefore, it is necessary to have, in addition to the patent number, the year of its publication in order to properly identify the patent. Dates given: (1) Application, (2) complete acceptance.

**FRANCE.**—Numbering system similar to that of the United States. Previous to 1901 a description of the patent and one date only were published, while in many cases, at the discretion of the director of the French Patent Office, only the title of the patent, without any description or specifications, were published. These latter have been indicated "unpublished" in the following lists. Since 1901 complete dates and specifications are available. Dates given: (1) Application, (2) patenting, (3) publication.

**GERMANY.**—Numbering system similar to the United States. Dates given: (1) Patenting, (2) publication.

### IV. TABULATION OF PATENTS.

#### 1. GROUP I.—AMINES.

Ger. 5786. Aktien-Gesellschaft Croix. Pat. October 6, 1878; Pub. July 7, 1879.

*Title:* Process of manufacturing alkali carbonates using trimethylamine.

Describes the reaction between potassium or sodium chloride with trimethylamine bicarbonate to form the corresponding alkali carbonates. One part of potassium chloride is mixed with four parts of trimethylamine carbonate, and the mixture saturated with carbon dioxide to form potassium bicarbonate. Trimethylamine hydrochloride is left in solution.

Ger. 9376 (addition to Ger. 5786). Aktien-Gesellschaft Croix. Pat. September 9, 1879.

Specifies trimethylamine from beet molasses, as well as monomethylamine, dimethylamine, monopropylamine, monoisobutylamine in addition to trimethylamine.

Fr. 219180. Quantin. Pat. February 5, 1892.

*Title:* Separation of amines from ammonia by precipitation as magnesium ammonium phosphate.

To separate the methylamines from ammonia the crude mixture is distilled with milk of lime, and the distillate is collected in water, moist magnesium phosphate is then added, when, in the presence of much methylamine, the ammonia will be precipitated in 24 hours. The filtrate yields on distillation with milk of lime the methylamines free of ammonia.

Ger. 71328. Kossel and Schloemann. Pat. May 3, 1893; Pub. October 2, 1893.

*Title:* Separation of primary from secondary and tertiary amine bases.

Metaphosphoric acid is used to separate primary amine bases, diamines, and diimides from other bases. Amine bases and diamines of aromatic and aliphatic groups give compounds insoluble in water. The imid bases and nitrile bases give soluble metaphosphates.

Fr. 308407. Keppich. Pat. February 23, 1901.

*Title:* Process for separating amines from ammonical waters. (Unpublished.)

Ger. 270260. Schmitz, K. Pat. June 3, 1913; Pub. February 12, 1914.

*Title:* Process for the preparation of trimethylamine.

Trimethylamine is prepared from ammonium salts and formaldehyde by heating a mixture of dry ammonium salt and dry trioxymethylene or paraformaldehyde for a short time to a high temperature in open vessels provided preferably with a reflux condenser without the application of pressure.

Br. 14493/13. Bayer & Co. App. June 23, 1913; Acc. April 30, 1914.

*Title:* Improvements in and relating to the manufacture and production of dimethylaminoxymethane and dimethylamine.

Dimethylamine is prepared by treating trimethylamine salts with hypohalous acids and their salts, and treating the dimethylhalogen amine, such as dimethylchloroamine thus formed, after isolation, with reducing agents, such as bisulphite.

Br. 127740. Rintoul, Thomas, and Nobel's Explosives Co. App. June 15, 1918; Acc. June 12, 1919.

*Title:* Improvements relating to the preparation of amines.

Tertiary amines are separated from admixed primary or secondary amines by treating the mixture with ethyl chloroformate to convert the primary or secondary amines into urethans; the unattacked tertiary base is removed from the product by washing with dilute acid and is removed from the acid solution by treatment with alkali; the separated urethan is hydrolyzed to give the primary or secondary amine. An example is given of the treatment of crude dimethylaniline containing monomethylaniline.

Br. 128372. Rintoul, Thomas, and Nobel's Explosives Co. App. June 15, 1918; Acc. June 16, 1919.

*Title:* Improvements relating to the preparation of amines.

Tertiary amines are separated from admixed secondary amines by treating the mixture, at low temperatures, with phosgene to convert the secondary amine into the corresponding urea chloride; if the tertiary amine is in excess, the separation can be effected in one stage.

## 2. GROUP II.—AMMONIA.

## (a) PRODUCTION OF AMMONIA FROM WASTE WATER, DISCARD MOLASSES, OR OTHER SUGAR WASTES.

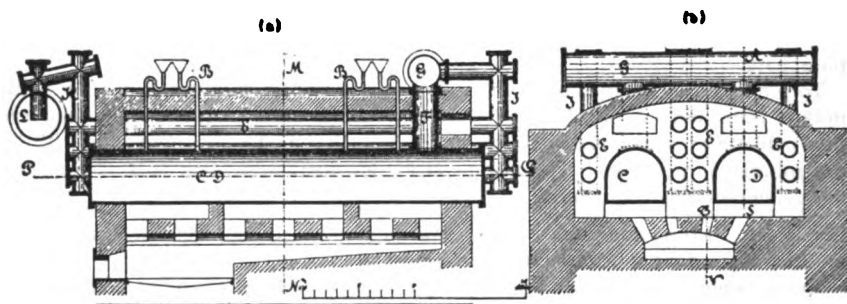


FIG. 1.—Ger. 15751.

Ger. 15751. Haring, Ehrenberg & Co., and Baswitz. Pat. April 2, 1880; Pub. December 6, 1881.

*Title:* Improved process for the dry distillation of molasses waste water, sugar elution water, and osmosis waste water for the recovery of ammonia.

Waste water is concentrated to 1.35 to 1.39 specific gravity and introduced into a retort at dark-red heat to cause immediate gasification. The gases are led through other heated tubes, at the side of the retort, which are filled with solid materials, such as clay, chalk, or chamotte. The chief product is ammonium sulphate and some methyl alcohol.

Ger. 11543. Ernst, E. Pat. February 4, 1880; Pub. October 16, 1880.

*Title:* Improvements in the process for conservation of nitrogen in waste water by the addition of sulphuric acid.

To concentrated waste water of 45–55° B. is added 15 per cent of 66° sulphuric acid while the waste water is hot; then 15 per cent dry powdered charcoal from soft woods is added and the whole changes to a dry mass without loss of nitrogen.

Ger. 13871. Ernst, E. Pat. October 6, 1880; Pub. May 30, 1881.

*Title:* Improvement in the dry distillation of molasses waste water.

Concentrated waste water is mixed with peat, calcium oxide, and fatty oil and the mixture dry distilled. The lime sets free ammonia and the oils enrich the fuel gases produced. Describes retort for process.

Ger. 14212 (addition to Ger. 11543). Ernst, E.

*Title:* Improvement in the process of utilizing molasses wastes through the addition of sulphuric acid and peat.

Specifies the use of all fluid molasses residues in the main patent.

Ger. 14433. Brosche, Sohn, F. X. Pat. July 9, 1880; Pub. July 28, 1881.

*Title:* Improvements in the process of recovery of nitrogen as ammonia from molasses waste, elution waste water, and osmosis waste water.

Ammonia is recovered from waste waters, as indicated in the title, by distillation over potash lime prepared from the waste-water ash and lime.

Ger. 15702. Badische Gesellschaft für Zucker Fabrikation. Pat. December 4, 1880; Pub. November 16, 1881.

*Title:* Improvements in the process of dry distillation of molasses waste water for the recovery of carbon, ammonia, methyl alcohol, and fuel gas.

Sodium hydroxide, prepared from the process itself, is added before distillation so that trimethylamine is not formed and ammonia only is recovered.

Ger. 43345. Meyer, E. Pat. August 28, 1887; Pub. April 28, 1888.

Br. 17347/87. Meyer, E. App. December 16, 1887; Acc. December 15, 1888.

Fr. 187573. Meyer, E. Pat. December 13, 1887.

U. S. 396705. Meyer, E., assignor to Carl Uhl & Co. App. September 15, 1888; Pat. Jan. 22, 1889.

*Title:* Obtaining ammonia and oxalic acid from sugar waste.

Waste water is added to caustic soda or potash in the proportions of 1 waste water to 8 caustic alkali, and heated. The greater part of the organic matter is destroyed, the nitrogen escaping as ammonia or amines, which are treated by well-known means, while in the molten mass a considerable quantity of oxalates are formed. The molten mass in the retort is run off and treated for oxalic acid, etc.

The patent specifies the addition of molasses or waste water in small doses and at intervals to prevent a violent evolution of ammonia.

Ger. 47190 (addition to Ger. 43345). Carl Uhl & Co. Pat. September 7, 1888; Pub. April 8, 1889. (See last paragraph above.)

U. S. 486647. Sternberg, L., assignor to American Sugar Refining Co. App. January 5, 1892; Pat. November 22, 1892.

Fr. 226024. Sternberg, L., assignor to American Sugar Refining Co. Pat. November 30, 1892.

Ger. 71408. Sternberg, L., assignor to American Sugar Refining Co. Pat. December 1, 1892; Pub. October 2, 1893.

Ger. 78442. Sternberg, L., assignor to American Sugar Refining Co. Pat. November 22, 1892; Pub. November 10, 1894.

*Title:* Process for obtaining ammonia and other salts from molasses.

Waste lyes from sugar manufacture are concentrated, then mixed with crushed coke, waste-water ash, etc., previous to calcining in closed retorts similar to those used for revivifying bone black. Superheated steam is introduced, and the nitrogen of the organic bodies is theoretically converted to ammonia. The ammonia liberated is led into sulphuric acid or into a tower of loose bricks, over which trickles a stream of ammonium sulphate solution containing free sulphuric acid. After absorption of the ammonia, the inert gases are passed back into the retort to prevent the decomposition of the ammonia. The residue in the retort is leached for alkalies or used to absorb more concentrated waste water.

Ger. 81401. Reichardt, H. Pat. February 12, 1893; Pub. November 5, 1895.

*Title:* Purification of ill-smelling gases from the waste-water ovens.

The alkaline waste water is carbonated by bringing it in contact with the hot gases from the waste-water oven, which contain carbon dioxide and are at a temperature of 250-400° C. The waste water is thus saturated and is then evaporated and the ash ignited. The volatile nitrogen-containing bases (chiefly amines) and ammonia are also purified.

Ger. 81341. Meyer, E. Pat. August 28, 1894; Pub. May 4, 1895.

*Title:* Process for the dry distillation of molasses waste water.

The process yields ammonia, which is set free by mixing lime-free molasses residues with an excess of alkali aluminum phosphate, the ammonia being absorbed and purified in known manner. Treatment of the raw alkaline aluminum phosphate yields aluminum oxide, calcium phosphate, potassium and sodium phosphates or a composite fertilizer direct. Lime is removed from the molasses to prevent reversion of the phosphate.

Ger. 86400. Offene Handelsgesellschaft. H. & W. Pataky. Pat. July 1, 1894; Pub. March 20, 1896.

*Title:* Recovery of ammonia and alkali carbonates from the residual lyes of desugarizing processes and from the manufacture of alcohol.

The lyes are evaporated to 70° Brix and added to  $\frac{1}{2}$  to 1 part of calcined alumina. This mixture is heated in iron retorts at red heat. The charge does not sinter. Ammonia is absorbed by water or sulphuric acid. The fuel gases are used for heating the retorts. The loose residue in the retorts is leached with water, the insoluble portions being reused until the alumina is exhausted. Potassium and sodium aluminates or carbonates and aluminum hydroxide are removed from the process, depending upon the method of treatment by evaporating or carbonating.

Ger. 89147. Matthiessen, F. O. Pat. February 21, 1895; Pub. October 7, 1896.

*Title:* Process of manufacture of ammonia from volatile organic nitrogenous substances, using aluminate contact masses.

Gases from the distillation of molasses waste water are conducted over glowing contact substances consisting, in the main, of alkali or alkaline earth aluminates, formed by heating bauxite and waste-water ash. Their reaction capacity is unlimited, as they do not combine with carbon dioxide and their basicity is constant.

Ger. 93397. Matthiessen, F. O. Pat. February 21, 1895; Pub. July 14, 1897.

*Title:* Process for obtaining ammonia from molasses waste water.

Molasses waste, alkali aluminate, and alumina are mixed and dried at a low temperature to keep the mass from sintering, then raising the temperature to liberate the ammonia. The alkali aluminate is a permanent basic contact body. After ignition, the contact mass is pulverized and used again, while any excess is treated as outlined in Ger. 86400. This process requires a lower temperature than previous patents. The contact body is formed into briquets.

U. S. 557166. Sternberg, L., assignor to American Sugar Refining Co. App. November 9, 1895; Pat. March 31, 1896.

Br. 7002/96. Sternberg, L., assignor to American Sugar Refining Co. App. March 31, 1896; Acc. August 15, 1896.

*Title:* Process of obtaining ammonia from waste-sugar lyes.

An aluminate of an alkali or alkaline earth is used as a carrier for waste lye or molasses. Upon being heated the gases are passed through potassium aluminate and alumina and changed to ammonia. The aluminate is made into bricks of  $1\frac{1}{2}$  parts of bauxite to 1 part of crude potash. The lye is concentrated to 75° Brix, mixed with alumina and an aluminate to form a plastic mass, forming into bricks and then drying and heating to redness, forming an incandescent contact body which transforms nitrogen into ammonia.

Ger. 118795. Besemfelder, E. R. Pat. June 11, 1899; Pub. March 20, 1901.

Ger. 121222 (addition to Ger. 118795). Besemfelder, E. R. Pat. June 11, 1899; Pub. March 20, 1901.

U. S. 689780. Besemfelder, E. R. App. September 29, 1899; Pat. December 24, 1901.

*Title:* Method of making ammonia from waste products.

The process is carried out by one of the following methods: (1) Dry distills liquors, conducting the gas over heated aluminate; through alkali to absorb cyanides, then over calcium diphosphate. (2) Dry distills in contact with alumina, conducting the gases as in (1). (3) Distills as in (2), adding coke to the mixture, and while in a glowing state blasting with air and steam to form water gas, conducting same in contact with the quantity of the waste and alumina undergoing distillation and then conducting the gas as in (1).

Ger. 209114. Effront, J. Pat. December 11, 1906; Pub. April 20, 1909.

Br. 28108/06. Effront, J. App. December 10, 1906; Acc. May 30, 1907.

U. S. 868976. Effront, J. App. December 13, 1906; Pat. October 22, 1907.

Fr. 369630. Effront, J. App. August 22, 1906; Pat. November 20, 1906; Pub. January 16, 1907.

*Title:* Process for the utilization of nitrogen in distillery residues.

The residues are treated with sodium bisulphate and heated in a closed vessel to 180–200° C., a current of air meanwhile passing through the vessel. About one-half the ammonia is recovered in the form of salts. The residue is then powdered and heated to 700° C. in a current of superheated air and steam. This distillation contains the remainder of the ammonia and the methyl alcohol. Molasses residues are treated preferably with resin in place of the bisulphate, and dried in an atmosphere consisting alternately of air and carbon dioxide, the vapors being collected in acid.

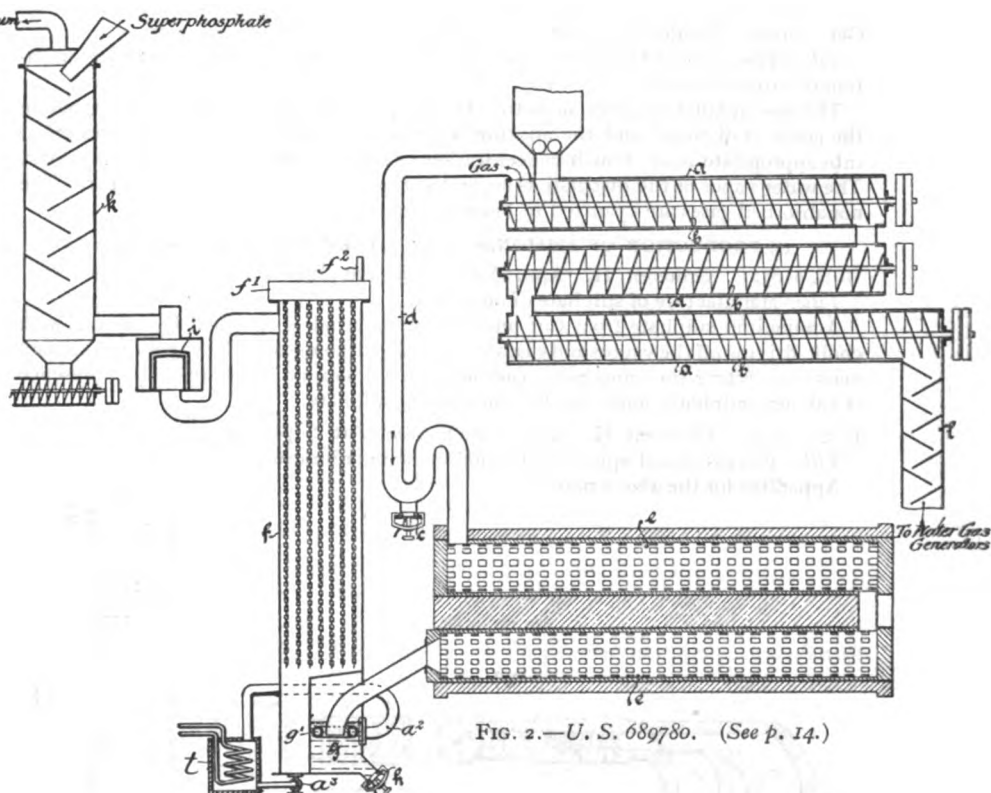


FIG. 2.—U. S. 689780. (See p. 14.)

Fr. 382689. Effront, J. App. October 8, 1907; Pat. December 14, 1907; Pub. Feb. 13, 1908.

*Title:* Process of recovery of ammonia by fermentation of nitrogenous organic substances.

The residues are fermented with a butyric ferment in an alkaline medium. The ferment is acclimatized in the presence of acid amides.

Fr. Addition No. 9148. Effront, J. App. April 1, 1908; Pat. June 17, 1908; Pub. August 29, 1908. (See Fr. 382689.)

Ger. 215531. Societe Anonyme de Recuperation de Produits Chimiques "Procede Effront." Pat. May 8, 1908; Pub. October 27, 1909.

*Title:* Process of obtaining ammonia and fatty acids through the action of ferments of albumen and their reaction products.

Distillery wash, sugar manufacture waste, and peat extracts may be treated with ferments under certain conditions for the formation of ammonia and fatty acids (acetic, propionic, butyric).

Ger. 270325. Gouthiere, H. and Cie., and Ducancel, P. Pat. November 7, 1911; Pub. February 16, 1914.

Fr. 442923. Gouthiere, H. and Cie., and Ducancel, P. App. July 1, 1911; Pat. July 2, 1912; Pub. September 12, 1912.

*Title:* Process for the preparation of ammonium sulphate.

A mixture of vinasse with ash from a previous distillation is dry distilled in the presence of water vapor and the ammonia is collected in sulphuric acid. The fuel gases produced are used for heating the retorts. An addition patent, dated October 18, 1912, covers the obtaining of glycerine from the process.

Ger. 339302. Muhlert, F. Pat. December 28, 1917; Pub. July 21, 1921.

*Title:* Process of obtaining ammonium salts and cyanogen compounds by gasification of nitrogen wastes.

The raw distillation gases, or better, the condensate which is produced by cooling the gases, is distilled, and the mixture of gases of ammonia and organic bases is led into appropriate acid of such concentration as to just neutralize the ammonia, etc. The water vapor of the distillate is separated from the gases in known manner. The nonabsorbed gases are cyanized in known manner.

(b) PRODUCTION OF AMMONIA FROM OTHER INDUSTRIAL WASTES.

U. S. 216323. Grouven, H. App. May 9, 1878; Pat. June 10, 1879.

*Title:* Manufacture of sulphate of ammonia.

Ammonium sulphate from turf and similar material is obtained by mixing with chalk, driving off the vapors and gases by heat, and decomposing the vapors by a contact mass; converting the ammonium carbonate to ammonium sulphate in the presence of calcium sulphate; purifying the ammonium sulphate.

U. S. 247046. Grouven, H. App. June 6, 1881; Pat. September 13, 1881.

*Title:* Process of and apparatus for making ammonium sulphate.

Apparatus for the above patent.

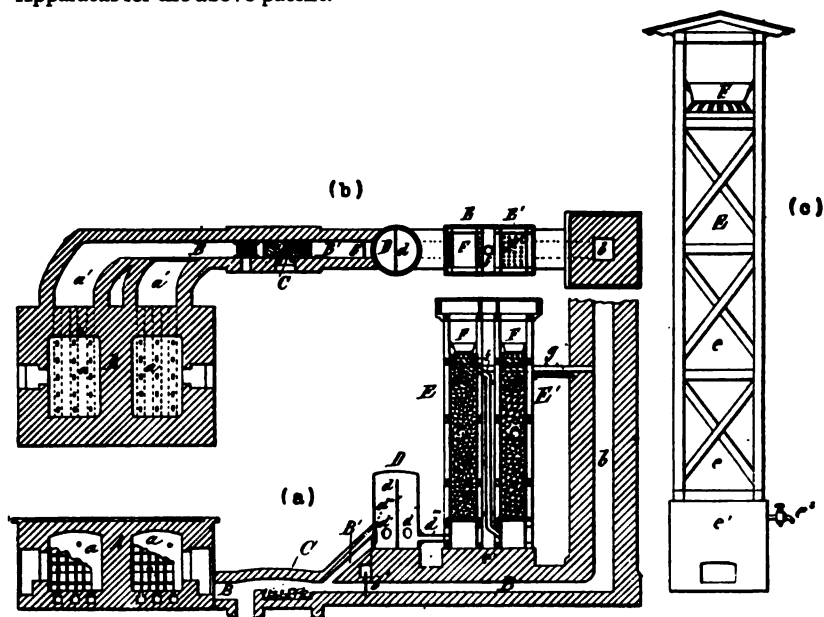


FIG. 3.—U. S. 232991.

U. S. 232991. Lorenzen, H. P. App. January 29, 1880; Pat. October 5, 1880.

*Title:* Method and apparatus for obtaining ammonia.

Ammonia is recovered from the distillation of nitrogenous substances by passing the gases through incandescent lime, cooling, and absorbing in sulphuric acid.

U. S. 278823. Rickman and Thompson. App. October 7, 1882; Pat. June 5, 1883.  
*Title:* Manufacture of ammonia and its salts.

Ammonia and its salts are prepared from animal excreta and other nitrogenous material by fermentation and distillation.

U. S. 282411. Terne, B., assignor of three-fourths to D. and E. P. Baugh, Philadelphia, Pa. App. December 11, 1882; Pat. July 31, 1883.

*Title:* Process of treating tank waters of slaughter houses.

Partial dry distillation of concentrated tank waters, leaving portion of the ammonia-containing materials in the residue to be used as a fertilizer.

U. S. 342237. Van Ruymbeke, J., assignor to National Chemical & Fertilizer Co. App. August 4, 1885; Pat. May 18, 1886.

*Title:* Process of obtaining ammonia.

By showering the nitrogenous liquors through forced currents of air within closed vessels over porous substances charged with putrid ferments.

U. S. 342238. Van Ruymbeke, J., assignor to National Chemical & Fertilizer Co. App. July 6, 1885; Pat. May 18, 1886.

*Title:* Process of making a fertilizer from tank waters.

By heating the tank waters to dryness at about 460° F.

U. S. 351412. Van Ruymbeke, J., assignor of one-half to W. F. Jobbins. App. July 27, 1885; Pat. October 26, 1886.

*Title:* Process of obtaining ammonia and illuminating gas from tank waters.

By dry distillation at not over 500° F.

U. S. 374618. Nast, W. F. App. May 4, 1887; Pat. December 13, 1887.

*Title:* Obtaining ammonia from manure, etc.

By heating the manure, etc., and conducting the gases in contact with heated basic materials, such as milk of lime, containing admixed sodium chloride (2 per cent) to facilitate or complete the reaction.

U. S. 488207. Kuntze, P. App. December 31, 1891; Pat. December 20, 1892.

Ger. 62589. Kuntze, P. Pat. April 8, 1891; Pub. December 27, 1892.

*Title:* Process of and apparatus for making ammonia.

Nitrogen in organic matter is left behind if the temperature is not carried high enough. Some escapes in the form of nitrites, organic bases of pyrrol and pyridine, amines, etc. The quantity of nitrogen products increases with progress of the dry distillation. After driving off the tar, the temperature rises and nitrogen as ammonium cyanide is formed in considerable quantity. This process tends to fix all the nitrogen as ammonia by calcining and heating. Describes a complicated apparatus for obtaining ammonia from peat.

Ger. 87061. Pieper, C. (Inc.). Pat. June 28, 1894; Pub. May 20, 1896.

*Title:* Process of treating nitrogenous substances for the recovery of ammonia and coke.

Peat or nitrogenous bodies are heated in retorts heated from the outside, from which the air is excluded. Sufficient steam is introduced for ammonia formation, also diminishing the loss of btu's if water gas forms. The temperature of the reaction is kept under the dissociation temperature of ammonia. The mixture of ammonia, hydrogen, and carbon dioxide passes through sulphuric acid. Nitrogen-free carbon remains in the retort. It appears that the evolution of gas from the peat, etc., must be complete before the steam is admitted.

Ger. 93705. Pieper, C. (Inc.), and Fellner and Ziegler. Pat. November 10, 1896; Pub. September 11, 1897.

*Title:* Process of recovery of ammonia from nitrogenous substances in continuous operation.

Improvement in Ger. 87061 to permit continuous operation. The material is conducted through a series of steaming chambers, which are so constructed with their fuel-gas supply, etc., that one or more of the units may be cut out without interfering with the process. The products of the gasification are kept separate. Steam used is recovered from the drying process.

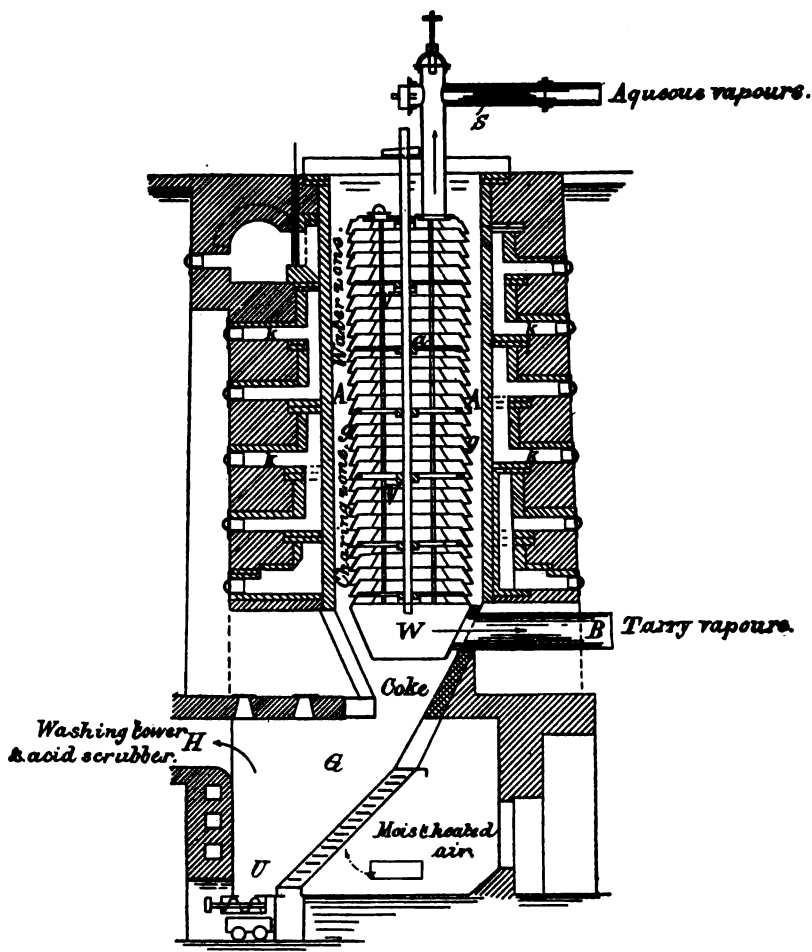


FIG. 4.—U. S. 488207. (See p. 17.)

Ger. 93706. Pieper, C. (Inc.), and Fellner and Ziegler. Pat. November 10, 1896; Pub. August 31, 1897.

*Title:* Process of utilization of nitrogenous substances.

Gases from the first distillation and steaming process are kept separate. The distillation products are freed from dust and dried, all condensable products removed, while the tar-free gaseous products of the steaming process are washed to remove the dust, and are then passed through acid to remove the ammonia.

Ger. 93746. Pieper, C. (Inc.). Pat. December 17, 1896; Pub. September 11, 1897.

*Title:* Process for the recovery of ammonia from nitrogenous substances and coke as per patent 87061.

A change in Ger. 87061. The distillation raw product is treated in a special apparatus with superheated steam in such quantity as is necessary for the decomposition of the material. The steam then meets only nitrogenous coke. Recovery of the ammonia is greater, and the time required is shorter. Makes use of countercurrent of coke and steam.

Fr. 353970. Guerrero, W. de Smirnoff. App. May 4, 1905; Pat. July 12, 1905; Pub. September 25, 1905.

*Title:* Process and apparatus for obtaining ammonium salts and other bodies.

Ammonium salts, methylene, acetates, tar, and charcoal are obtained from the dry distillation of residues from olives.

(c) SEPARATION OF THE AMMONIA FROM PROCESSES OF DISTILLATION OR INCINERATION.

Ger. 23594. Steffens, H. Pat. January 13, 1883; Pub. August 18, 1883.

*Title:* Recovery of ammonia from alcohol of desugarizing plants by precipitation with sulphuric acid.

Ger. 24549. Steffens, H. Pat. April 5, 1883; Pub. October 3, 1883.

*Title:* Recovery of ammonia from alcohol of desugarizing plants by precipitation with sulphuric acid or acid salts.

As well as sulphuric acid for the precipitation of ammonia from alcohol, carbon dioxide, phosphoric acid, potassium acid sulphate, sodium acid sulphate, or potassium acid phosphate may be used.

Fr. 331077. Societe F. Brunck. App. April 9, 1903; Pat. July 17, 1903; Pub. August 31, 1903.

Fr. Addition No. 3955 to above. Societe F. Brunck. App. November 5, 1904; Pat. February 2, 1905; Pub. April 5, 1905.

*Title:* Improvements in extracting ammonia from the gaseous products of dry distillation.

The gases are washed with concentrated sulphuric acid at 80-85° C. and the ammonium sulphate recovered directly in solid form. The addition patent specifies certain changes in the apparatus.

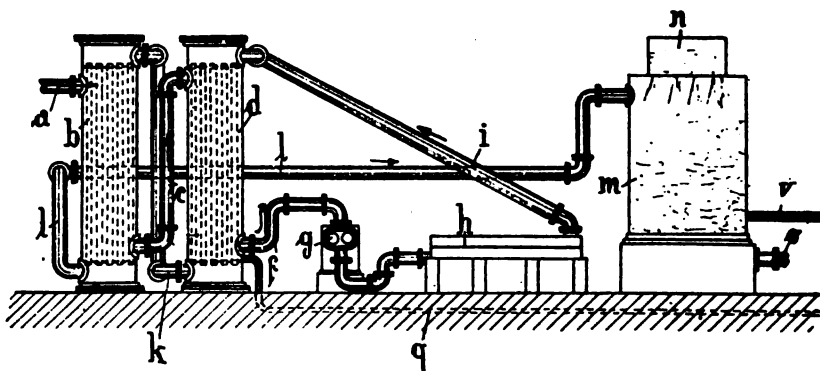


FIG. 5.—U. S. 84035. (See p. 20.)

U. S. 830983. Feld, W. App. January 4, 1906; Pat. September 11, 1906.

*Title:* Process of treating coal gas for extracting tar, water, and ammonia.

Tar and water are separated by means of sprays at a temperature between 40 and 500° C., preferably between 100 to 200° for tar, and above 40° and under 120° for water. Water is separated without absorbing ammonia, which is then recovered.

U. S. 851349. Feld, W. App. January 18, 1907; Pat. April 23, 1907.

*Title:* Extracting ammonia from gases.

Air is introduced into the retorts. The tar and water are separated in the usual way, and the gas passed into gypsum held in solution and suspension. Gases are produced from materials which are such that the gases contain less than 1 molecular proportion of carbon dioxide to 2 molecular proportions of ammonia. All ammonia is absorbed as above.

U. S. 846035. Koppers, H. App. September 2, 1905; Pat. March 5, 1907.

*Title:* Ammonia recovery apparatus and process.

The gas is cooled below  $72^{\circ}$ , the tar condensed and separated, the gas washed with acid to make a liquor which is saturated with the waste vapors obtained by treating said condensate with lime and steam.

U. S. 953959. Koppers, H. App. January 15, 1908; Pat. April 5, 1910.

*Title:* Recovering ammonia and tar from distillation gases.

By cooling to condense tar and water, separating the tar, scrubbing the gas with water to form an aqueous solution of ammonia. The condensate and aqueous solution are passed through a distilling column to separate ammonia, mixing the vapors from the distilling column with preheated air and conducting the mixture to a saturation bath containing sulphuric acid.

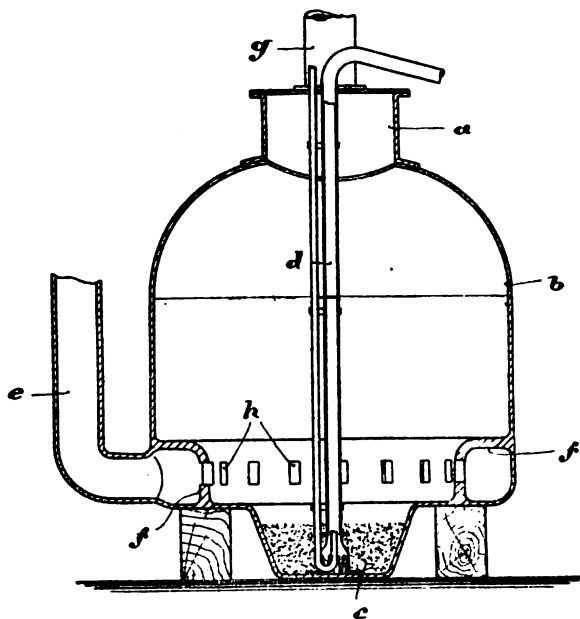


FIG. 6.—U. S. 953960.

U. S. 953960. Koppers, H. App. May 20, 1909; Pat. April 5, 1910.

*Title:* Recovering ammonia and tar from distillation gases.

Describes an ammonia saturation vessel for carrying out the process described in U. S. 953959.

U. S. 952560. Caro, N. App. June 28, 1909; Pat. March 22, 1910.

*Title:* Process of obtaining ammonium sulphate from gases.

By cooling the gases to  $15-20^{\circ}$  to separate tar and ammonia water, distilling the latter, partially drying the vapors thus formed, mixing them with the previously cooled distillation gases and conducting the mixture into a solution of ammonium sulphate of  $29-35^{\circ}$  B. containing about 5 per cent free sulphuric acid.

**(d) FURTHER PROCESSES FOR THE PRODUCTION OF AMMONIUM SALTS FROM THE GASEOUS CONSTITUENTS OF DRY DISTILLATION.**

Ger. 237524. Bueb, J., and Deutsche Continental Gas Gesellschaft. Pat. August 3, 1909; Pub. August 22, 1911.

Ger. 246017. Bueb, J., and Deutsche Continental Gas Gesellschaft. Pat. April 29, 1910; Pub. April 22, 1911.

U. S. 1018406. Bueb, J. App. April 12, 1910; Pat. February 27, 1912.

*Title:* Manufacture of ammonium carbonate.

Ammonia, carbon dioxide, and steam are passed through a tube heated above the decomposition point of ammonium carbonate and then cooled below 60° in a final chamber. The heat necessary for the reaction may be obtained by passing the tube through water heated to 60–90° C. The salt is deposited as a crust on plates cooled by water. The percentage of ammonia can be regulated by the temperature of the water through which the tube passes before reaction.

Ger. 252276. Bueb, J., and Deutsche Continental Gas Gesellschaft. Pat. September 12, 1909; Pub. October 22, 1912.

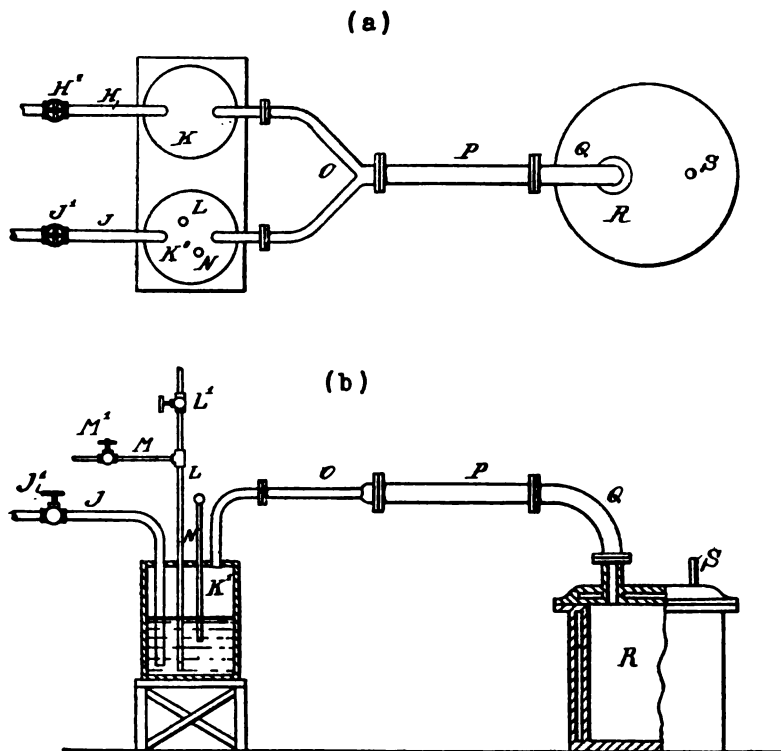


FIG. 7.—U. S. 1004361.

U. S. 1004361. Bueb, J. App. September 21, 1910; Pat. September 26, 1911.

*Title:* Method of making ammonium carbonate.

By adjustment of the temperature of the water used for heating the gases prior to the reaction a product may be obtained which contains any desired percentage of ammonia between 20 and 40 per cent. Special apparatus for the process is described.

## CROSS REFERENCES.

## Manufacture of Ammonia:

Ger. 9409. Aktien-Gesellschaft Croix. Group 4(b).

Fr. 485597. Dupont, L. Group 7(d).

Ger. 232878. Hauff. Group 4(c).

U. S. 1145484. Huber and Poindexter. Group 4(a).

Fr. 385139. Riviere, L. Group 6.

Ital. 135224. Vigano and Soldi. Group 6.

## 3. GROUP III.—APPARATUS.

## (a) APPARATUS FOR INCINERATING AND CALCINING WASTE WATER, ETC.

Fr. 75927. Wagner. Pat. April 30, 1867.

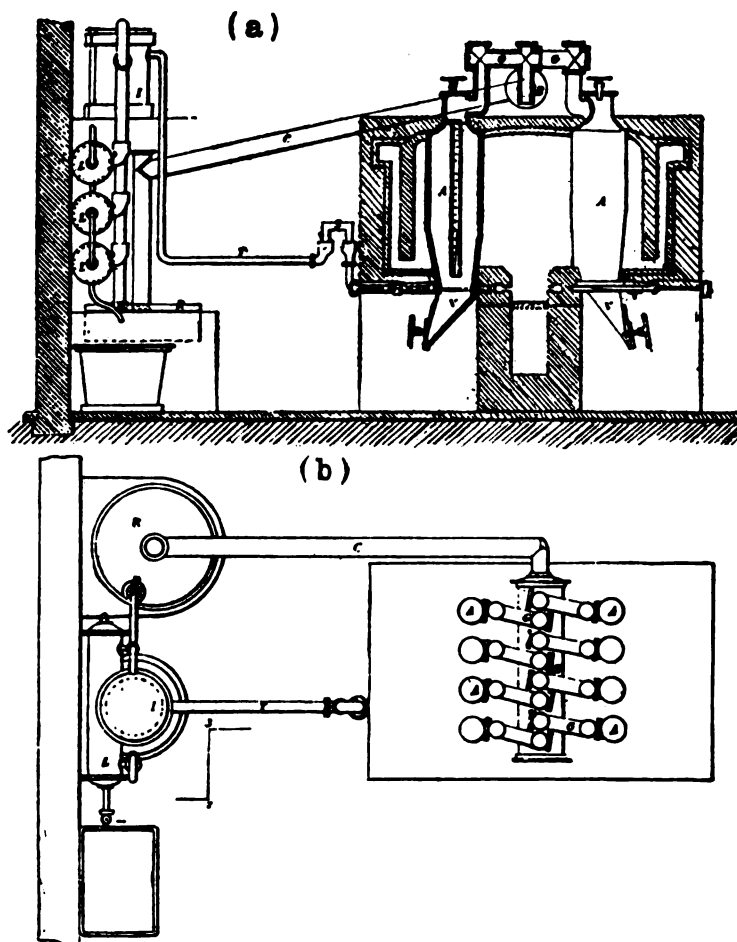
*Title:* Double effect reverberatory furnace for the incineration of distillery vinasse and of all combustible material. (Unpublished.)

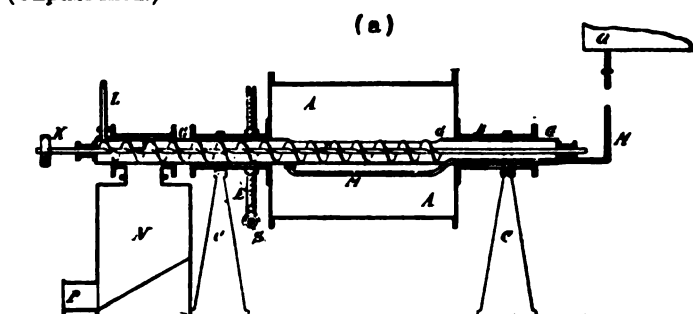
FIG. 8.—Fr. 122938.

Fr. 122938. Houzeau and Goutierre. Pat. March 1, 1878.

*Title:* Economic furnace for calcination and distillation of all materials with recovery of utilizable volatile products. (Unpublished.)

Fr. 139529. Farinaux and Laine. Pat. November 8, 1880.

*Title:* Furnace for evaporating and incinerating wool washings, vinasses, and such lyes. (Unpublished.)



(c)

(b)

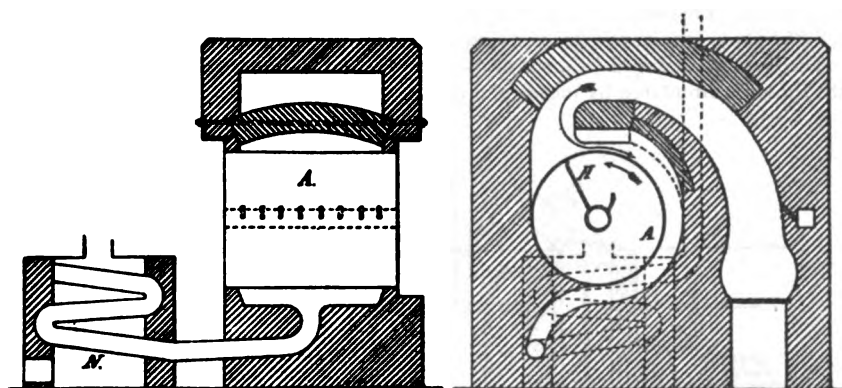


FIG. 9.—Ger. 17874.

Ger. 17874. Lederer and Gintl. Pat. May 28, 1881; Pub. April 24, 1882.

*Title:* Apparatus for the continuous carbonizing and distillation of molasses waste water.

Consists of a slowly revolving drum, mounted on a fire-brick setting through which gases are burned, into which molasses residues are pumped. As the dried residues reach the top they are scraped off and fall onto a conveyor screw and are taken outside the drum. The gases are taken off at another outlet.

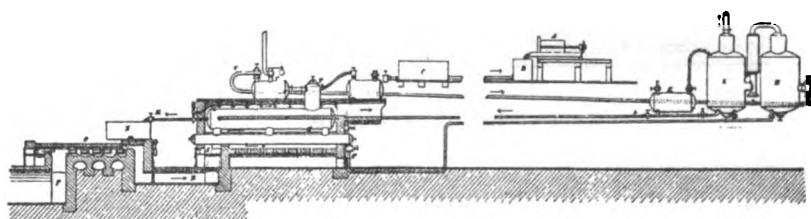


FIG. 10.—Fr. 154291.

Fr. 154291. Gamer, L. Pat. March 14, 1883.

Ger. 26236. Gamer, L. Pat. June 3, 1883; Pub. May 22, 1884.

*Title:* Continuous carbonizing retort for waste water with inclined separating walls on the hearth bed and dumping pit.

A set of ovens, each 4 m long and 1.6 m wide are arranged in a single setting. Several gates give access to the retorts. In each retort is an inclined fire brick which separates the floor of the oven into sections. Concentrated waste water enters the back of the oven and is pushed over these bridges toward the front section, where the incineration is completed. A grating is so arranged as to start the incineration process, but the oven is closed tight after being once started.

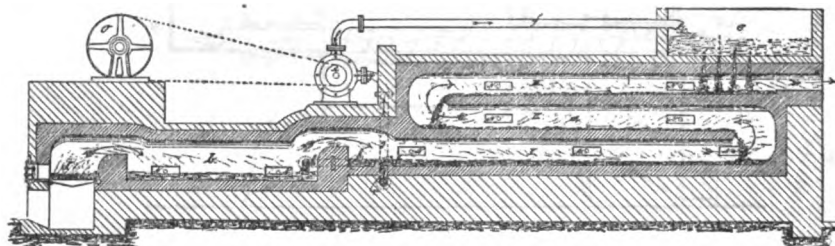


FIG. 11.—Ger. 26420.

Ger. 26420. Proeber, G. Pat. May 20, 1883; Pub. April 4, 1884.

*Title:* Oven for the evaporation and calcination of waste water.

The oven is arranged in a set of steps, or stages, one over the other, over which the liquor is circulated by means of a pump.

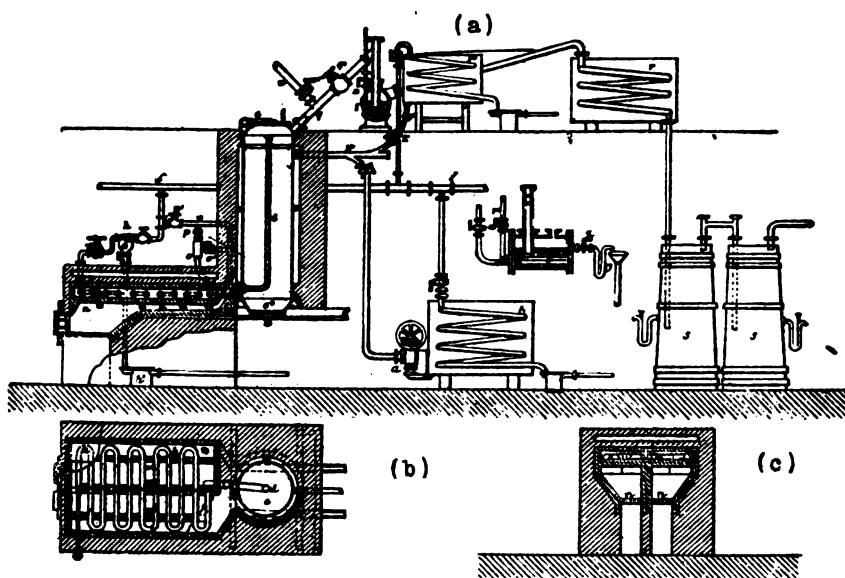


FIG. 12.—Fr. 184905.

Fr. 184905. Zwillingger, A. Pat. July 20, 1887.

Ger. 38419. Zwillingger, A. Pat. January 30, 1886; Pub. February 8, 1887.

*Title:* Improvement in the process of carbonizing molasses waste water.

An apparatus for combining the use of flue gases and superheated steam to evaporate waste water with the provision to absorb by-products.

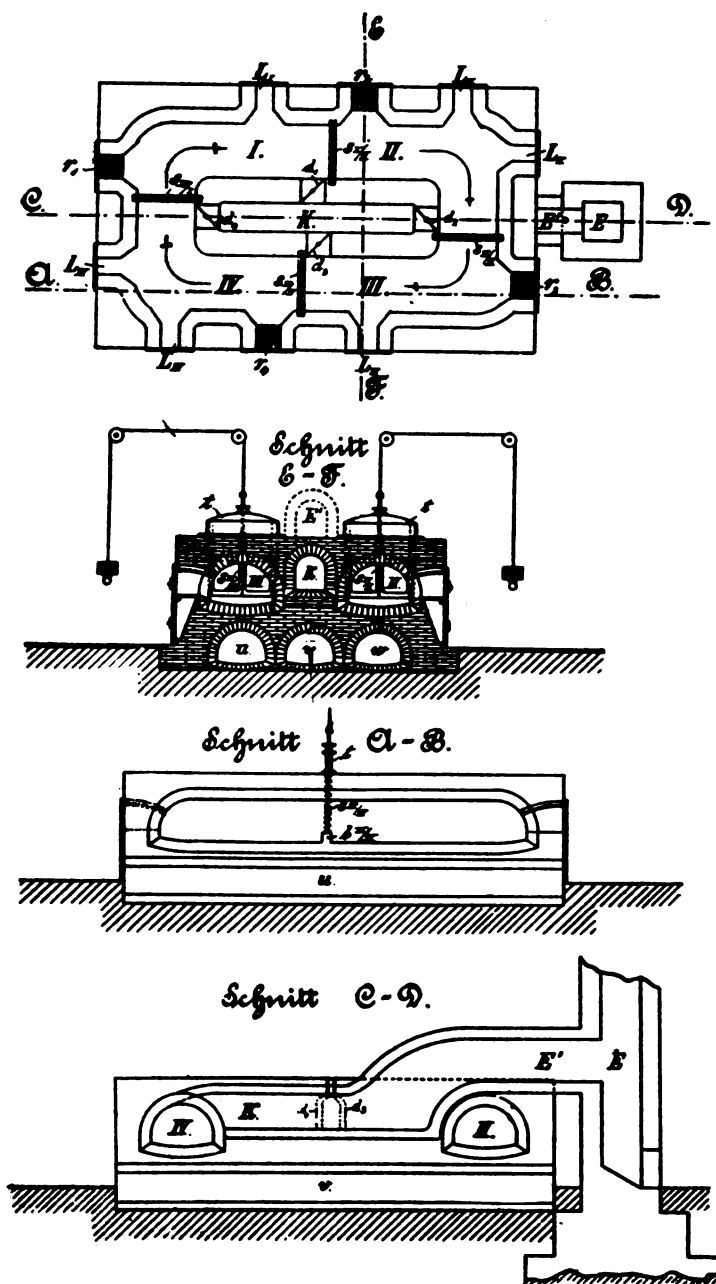


FIG. 13.—Ger. 61336.

Ger. 61336. Schwager, J. Pat. June 27, 1891; Pub. March 8, 1892.

*Title:* Furnace for the evaporation, distilling, and coking of organic substances contained in lyes.

A complicated and impractical series of ovens with many gates, valves, etc.

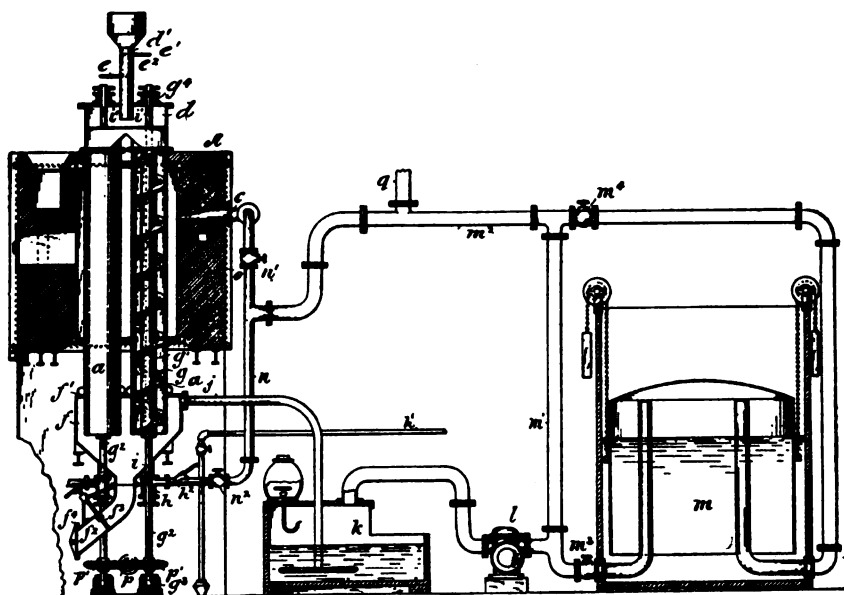


FIG. 14.—U. S. 522357.

U. S. 522357. Sternberg, L. App. October 19, 1893; Pat. July 3, 1894.

Title: Apparatus for obtaining ammonia.

Vertical retort for the distillation of nitrogenous liquids to produce ammonia or ammonium salts.

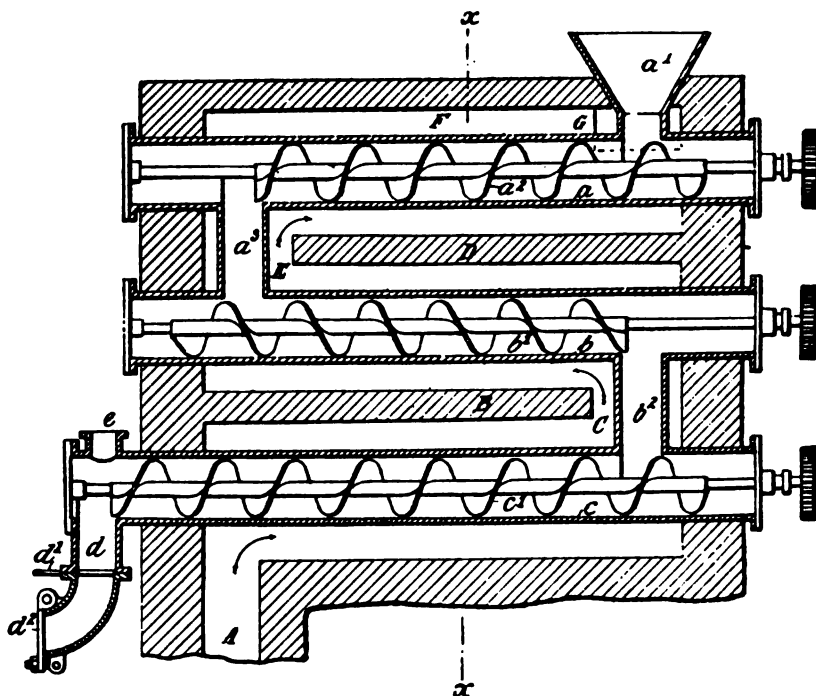


FIG. 15.—Ger. 105638. (See p. 27.)

Ger. 105638. Sternberg, L. Pat. August 10, 1897; Pub. September 22, 1899.

*Title:* Process of obtaining ammonia from residues of desugarizing or distillery slop.

Three retorts, one above the other, each equipped with a conveying screw for moving the mass from one retort to the one below.

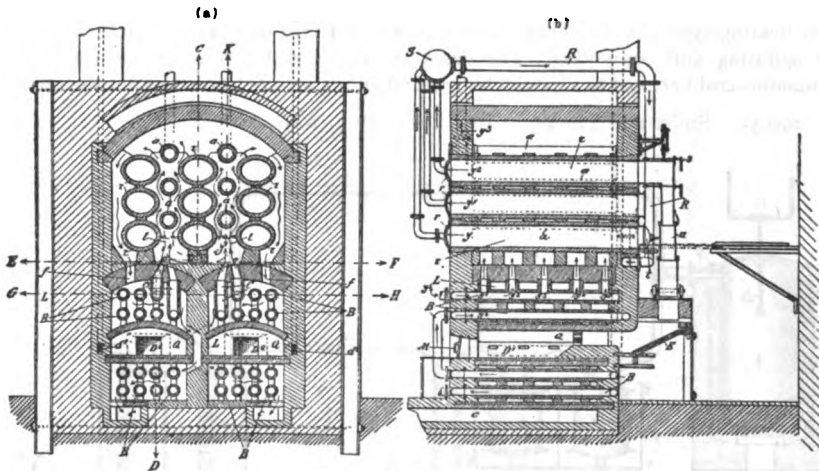


FIG. 16.—Ger. 108724.

Ger. 108724. Wenck. Pat. March 23, 1898; Pub. February 27, 1900.

*Title:* Combined distilling and calcining oven.

A set of horizontal ovens in a setting so arranged that the gases liberated are first freed of ammonia, returned through pipes between the retorts to convert further nitrogen to ammonia, and then conducted beneath the retorts to be used as fuel gas for heating the retorts.

Fr. 289951. Waissbein. Pat. June 15, 1899.

*Title:* Process of dry distillation or fractionation of solid or liquid matter by means of uncondensable gaseous products of the same distillation. (Unpublished.)

Austr. 1284. Petekker Zuckerraffinerie. Pat. January 15, 1900; Pub. May 10, 1900.

Fr. 291245. Petekker Zuckerraffinerie. Pat. July 28, 1899.

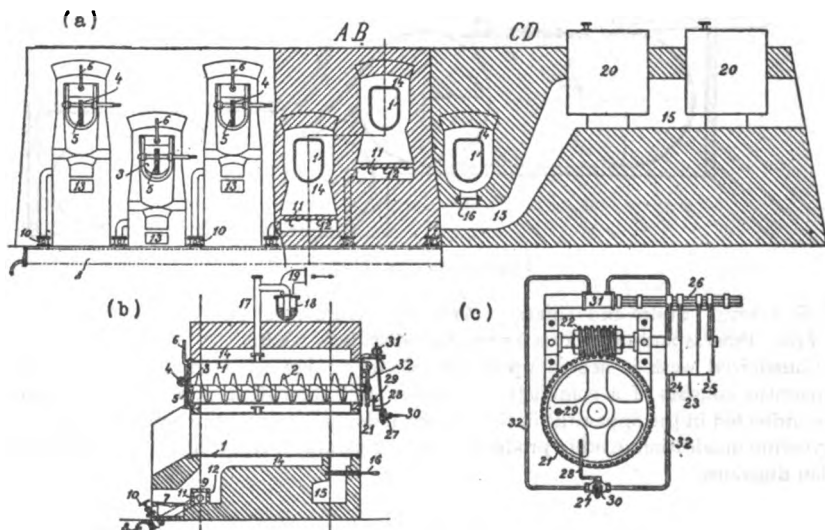


FIG. 17.—U. S. 666657. (See p. 28.)

U. S. 666657. Fischer, H. App. August 8, 1899; Pat. January 29, 1901.

Br. 15815/99. Fischer, H. App. August 2, 1899; Acc. October 28, 1899.

*Title:* A process of, and apparatus for, obtaining ammonia and its salts from spent liquor in sugar factories, and from vinasses.

The liquor is evaporated in special pans built into the flues. Each retort has its own heating system. The evaporated liquor is led into troughs in which are screws for agitating and conveying. The gases are conducted through a tar condenser, ammonia scrubber, and to a gasometer from whence they are burned under the retorts.

Fr. 296955. Sudre and Thierry. Pat. February 7, 1900.

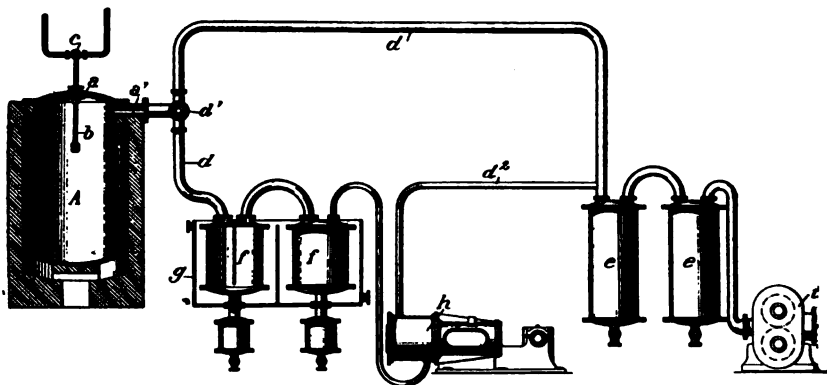


FIG. 18.—U. S. 669812.

U. S. 669812. Sudre and Thierry. App. February 15, 1900; Pat. March 12, 1901.

U. S. 712343. Sudre and Thierry. App. February 18, 1901; Pat. October 28, 1902.

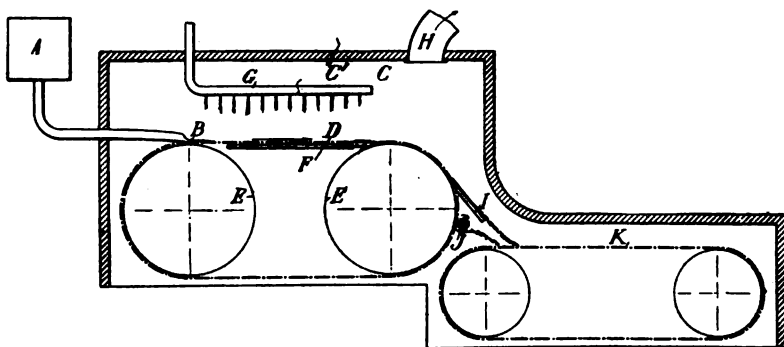


FIG. 19.—U. S. 732234.

U. S. 732234. Sudre and Thierry. App. August 29, 1900; Pat. June 30, 1903.

*Title:* Process and apparatus for treating distiller's wash.

Causticized wash is heated up to 500° C. to recover all possible products. The apparatus consists of a combustion chamber and absorption train. Improvements are indicated in the apparatus in the various patents to enable the patentee to recover glycerine in addition to other products. The apparatus is represented by complicated plan diagrams.

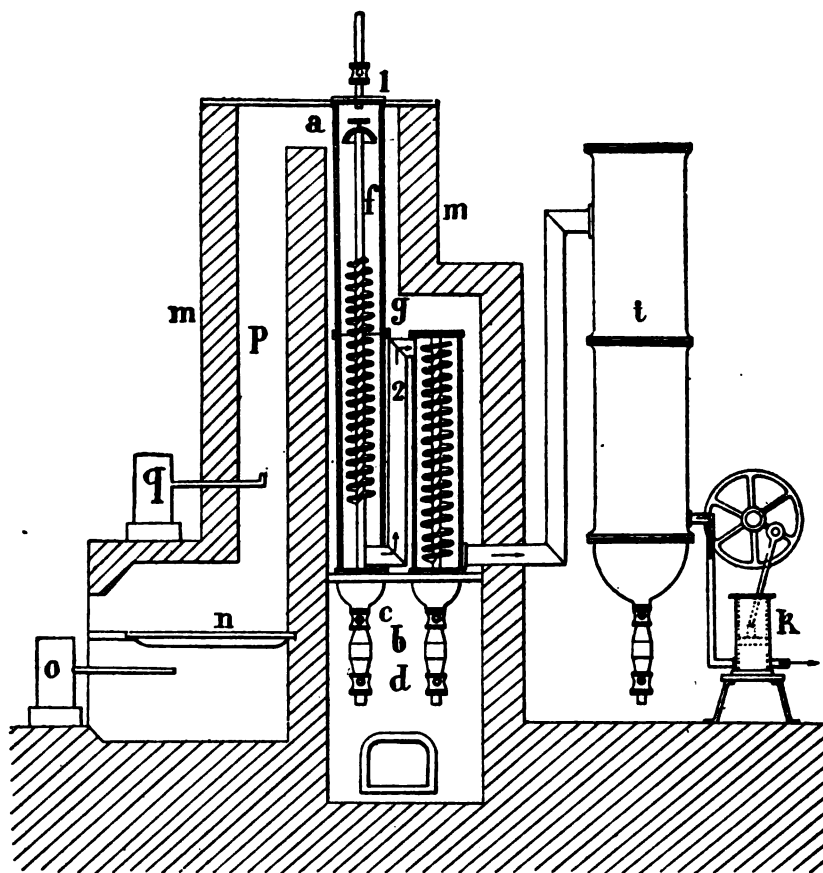


FIG. 20.—U. S. 810442.

U. S. 810442. Sudre, C. App. January 6, 1904; Pat. January 23, 1906.

*Title:* Process of treatment of vinasses.

A process for the extraction of glycerine in the form of a mixture of glycerine and water to be concentrated and producing a residue containing all the ammonia, which consists in rendering the vinasses acid and causing them to flow in a vacuum along a surface heated to a maximum temperature of  $300^{\circ}$  C. and causing the steam to have a gyratory movement to free it of the particles carried with it.

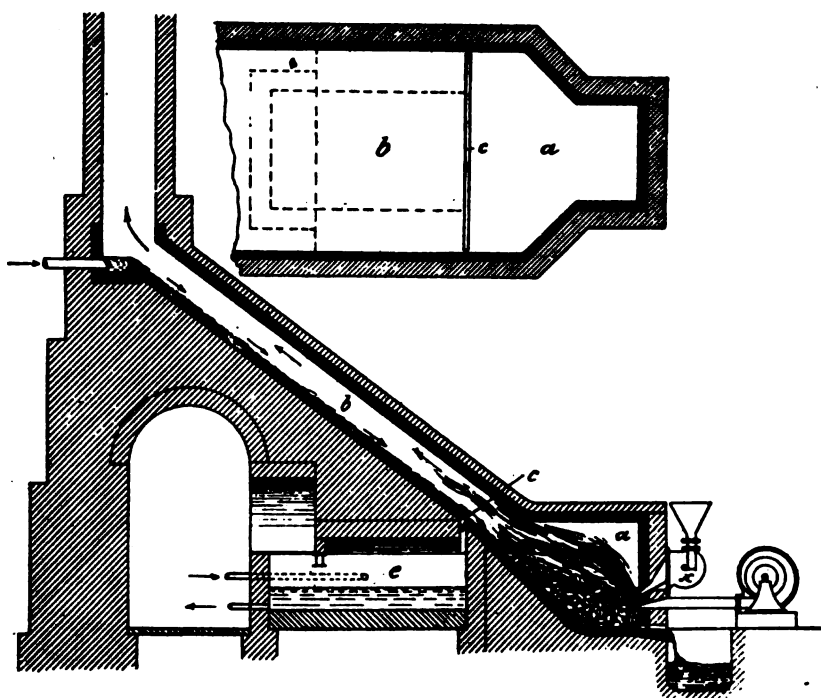


FIG. 21.—Ger. 128903.

Ger. 128903. Schwager, J. Pat. January 25, 1901; Pub. March 11, 1902.

*Title:* Retort with inclined flue for the evaporation of liquids which develop combustible gases.

The liquid is in direct contact with fuel gas. The gases are lost. The apparatus is more truly an incinerator than an evaporator.

(b) APPARATUS FOR EVAPORATING AND CONCENTRATING WASTE WATER.

Ger. 17869. Ernst, E. Pat. February 8, 1881; Pub. April 17, 1882.

*Title:* Molasses residues mixed with small coal, peat, shavings, etc.

Complicated retorts or ovens for preparing the mixtures described in the title.

Ger. 20710. Mey, F. H. C. Pat. July 2, 1882; Pub. January 15, 1883.

*Title:* Apparatus for drying of fruit, sand, brewery waste, and wastes of alcohol plants and sugar factories.

Furnace incorporating the use of an endless belt.

Ger. 24403. Bernard, A. Pat. January 11, 1883; Pub. October 9, 1883.

*Title:* Apparatus for the evaporation of organic liquids.

An apparatus for the evaporation of organic liquids, especially sugar wastes and elution waters, with the exclusion of air and at the temperature of a hot water bath, consisting of a retort with a stirring and conveying device in combination with a leaching device into which the dried mass arrives out of contact with the air.

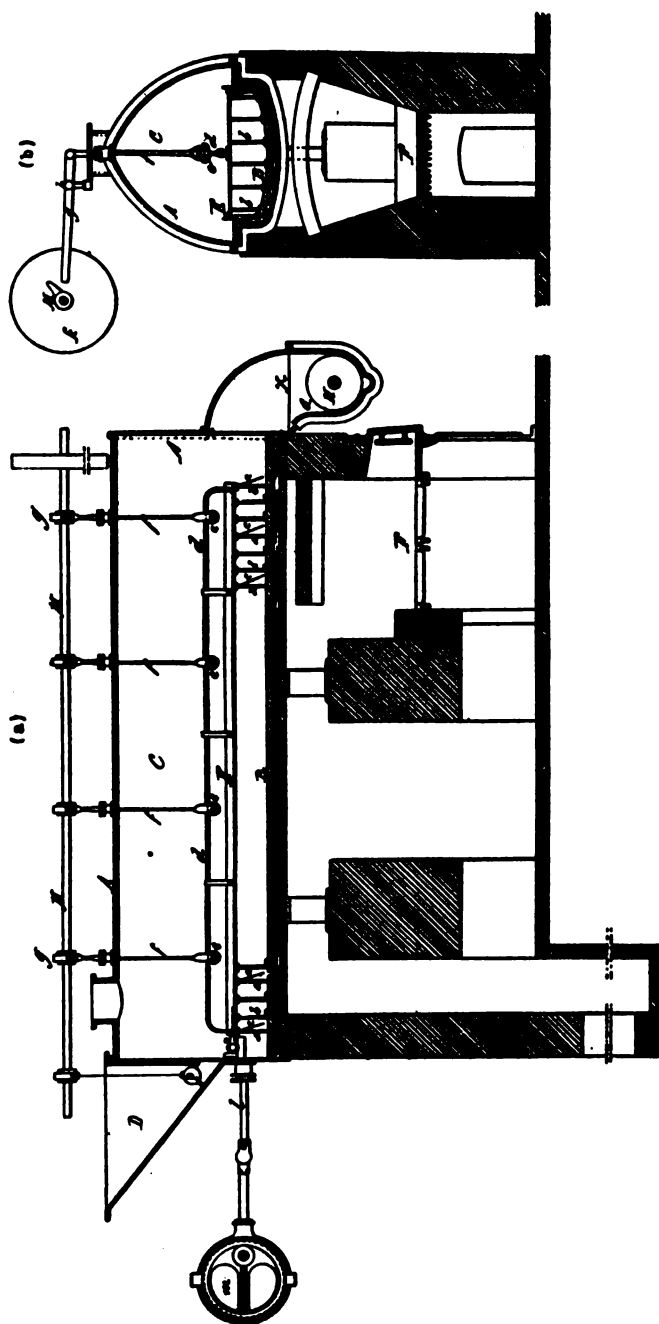


FIG. 22.—Ger. 24403. (See p. 30.)

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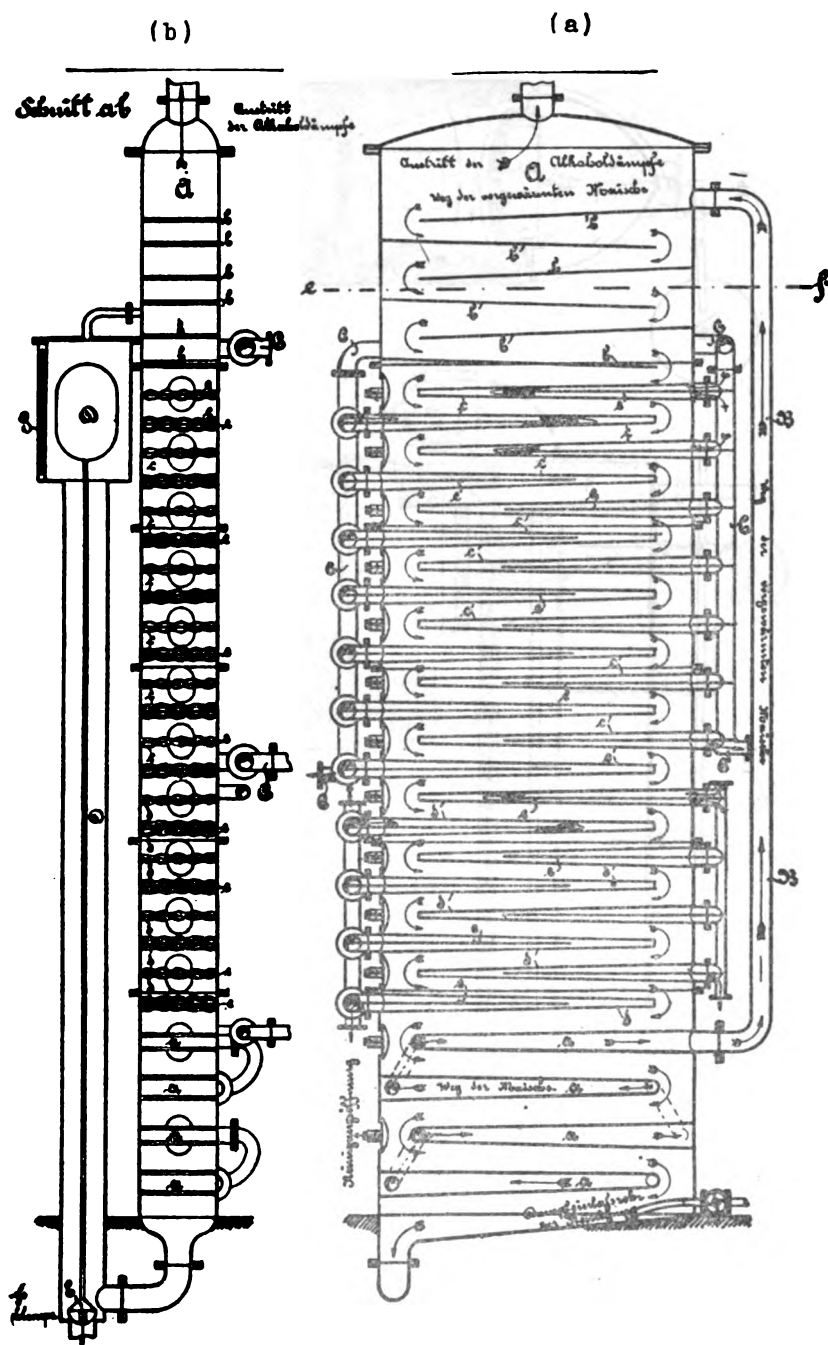


FIG. 23.—Ger. 25945.

Ger. 25945. Salzmann, C. Pat. May 13, 1883; Pub. February 18, 1884.

Title: Mash distilling apparatus for obtaining concentrated waste water.

Ger. 28828 (addition to Ger. 25945). Salzmann, C. Pat. February 22, 1884; Pub. October 1, 1884.

Complicated column still for the recovery of alcohol and concentrated waste water.

Ger. 28249. Plonnis, R. Pat. January 30, 1884; Pub. August 2, 1884.

Title: Apparatus for drying corn, grain, waste water, beet pulp, etc.

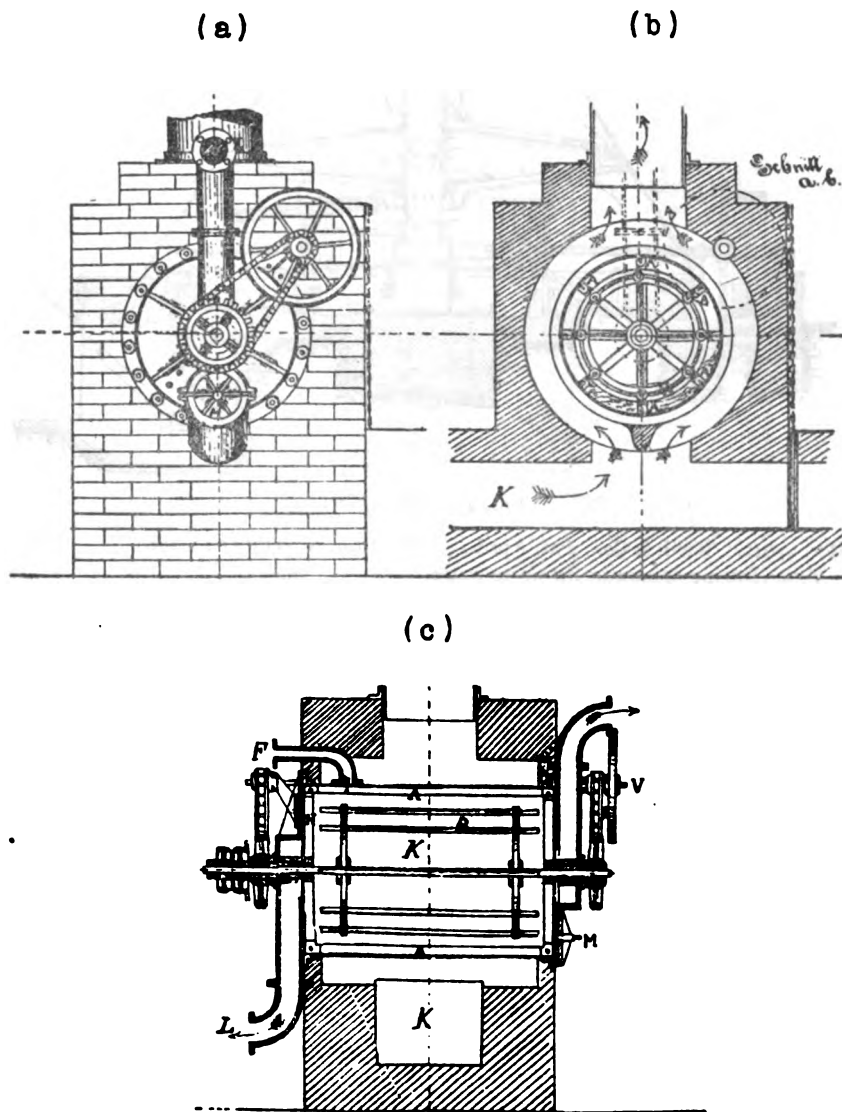


FIG. 24.—Ger. 35853.

Ger. 35853. Klaunig, O. Pat. July 21, 1885; Pub. June 23, 1886.

Title: Vacuum drying apparatus with stirrer for waste water and grain.  
Retort with rotating stirrer.

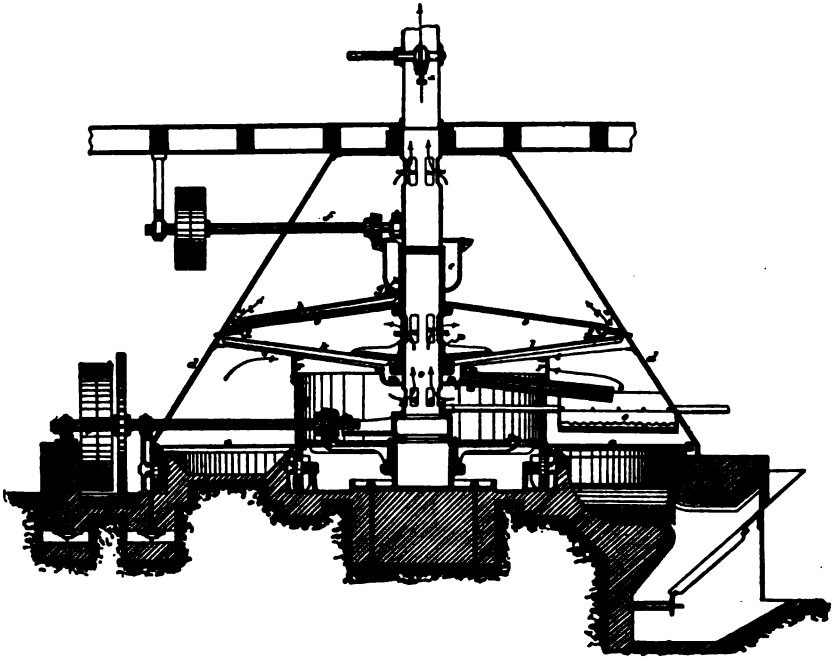


FIG. 25.—Ger. 37641.

Ger. 37641. Wirth & Co. Pat. April 13, 1886; Pub. November 20, 1886.

*Title:* Drying apparatus for waste water.

Large and complicated circular apparatus rotating about a central shaft.

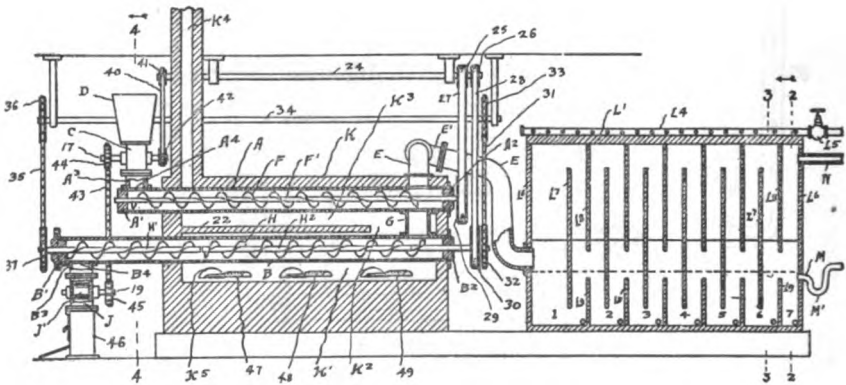
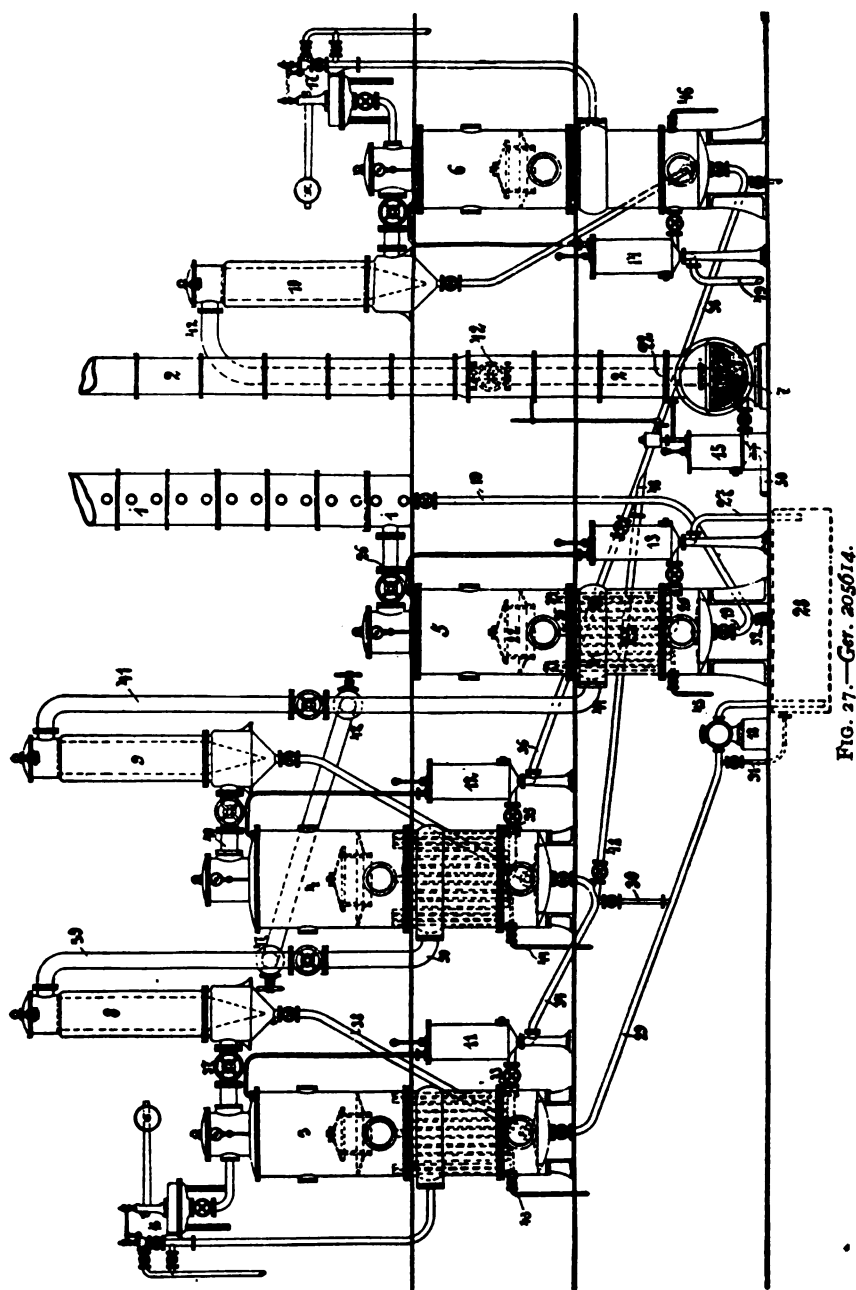


FIG. 26.—U. S. 1379876.

U. S. 1379876. Nottingham and Tuhey, assignors to American Nottingham Process Co. App. May 16, 1919; Pat. May 31, 1921.

*Title:* Apparatus for distillation.

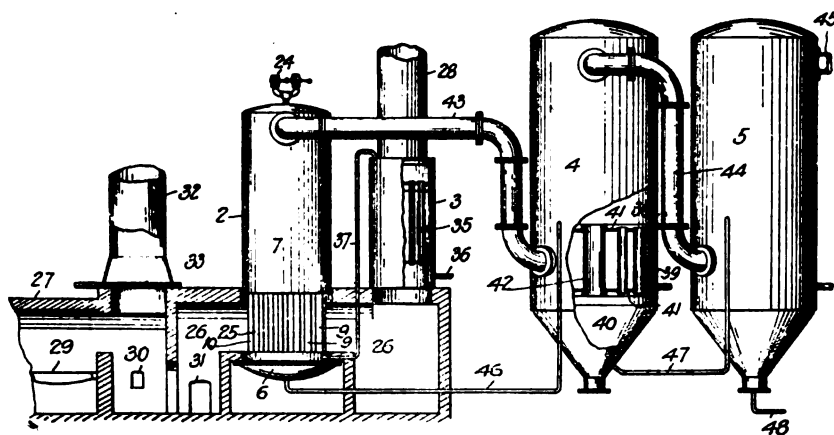
Material, such as corn cobs, is destructively distilled while passing successively through superposed horizontal tubular retorts provided with conveying screws.



Ger. 205614. Pampe, F. Pat. December 2, 1906; Pub. January 15, 1909.

Title: Process for the concentration of waste water.

A diagram gives a complicated plan of three-stage evaporators with various other units for use in the process.



(a)

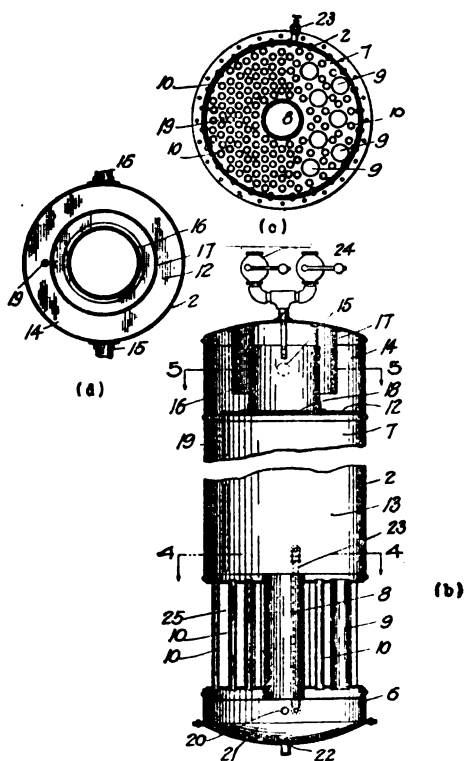


FIG. 28—U. S. 1385499.

U. S. 1385499. Schwarz. App. June 25, 1918; Pat. July 26, 1921.

Title: Evaporator.

For the evaporation of waste water from molasses or similar liquids; a tubular evaporator which may be heated by waste exhaust gases is described.

## (c) APPARATUS FOR RECOVERING AMMONIA FROM WASTE WATERS.

(a)

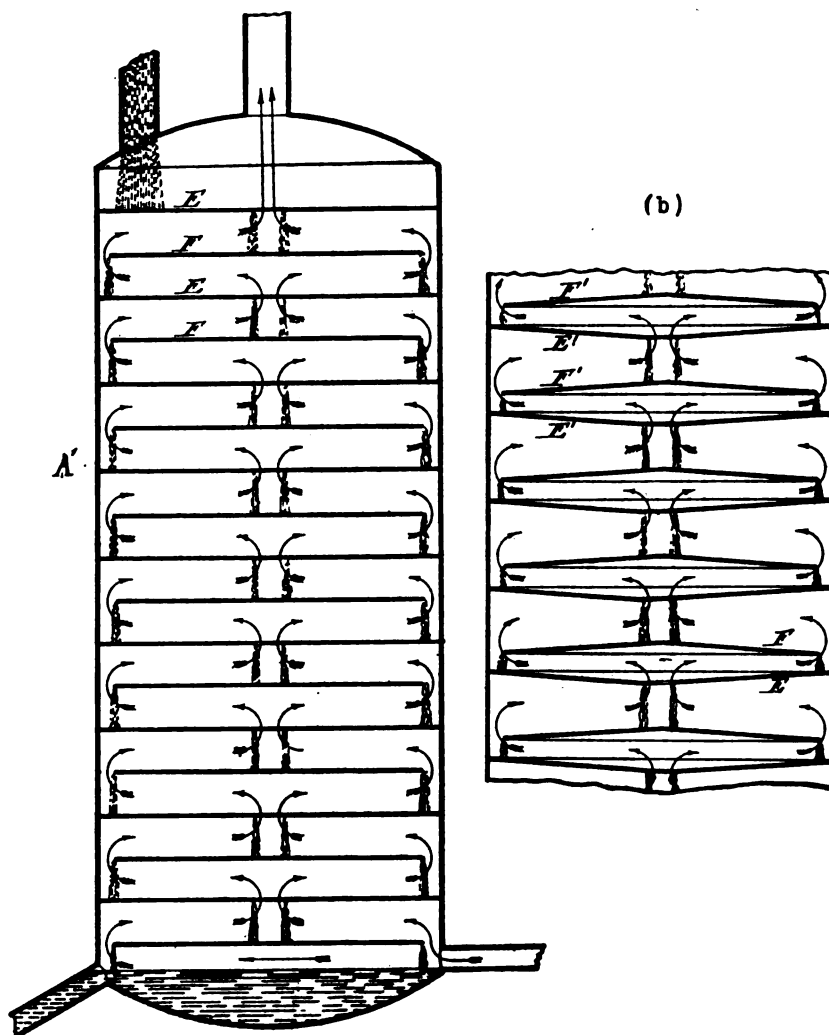


FIG. 29.—Ger. 27034.

Ger. 27034. Young, J. Pat. April 11, 1883; Pub. May 15, 1884.

*Title:* Apparatus for the recovery of ammonia from water of seal tanks and waste water of sugar factories.

A series of boxes arranged in steps or a tower similar to the modern ammonia still, where ammonia-containing liquids, previously warmed and treated with lime, come in contact with a countercurrent of steam.

Ger. 38596. Schiller, R. Pat. March 12, 1886; Pub. February 18, 1887.

*Title:* Apparatus for the recovery of ammonia contained in the alcohol or the waste water of the Mannoury molasses desugarizing process.

In the apparatus, ammonium bisulphate is exposed to the gases containing ammonia, changing it to ammonium sulphate. The apparatus is of wood, and composed of plates and arms so arranged to bring the ammonia lyes in contact with the bisulphate solution.

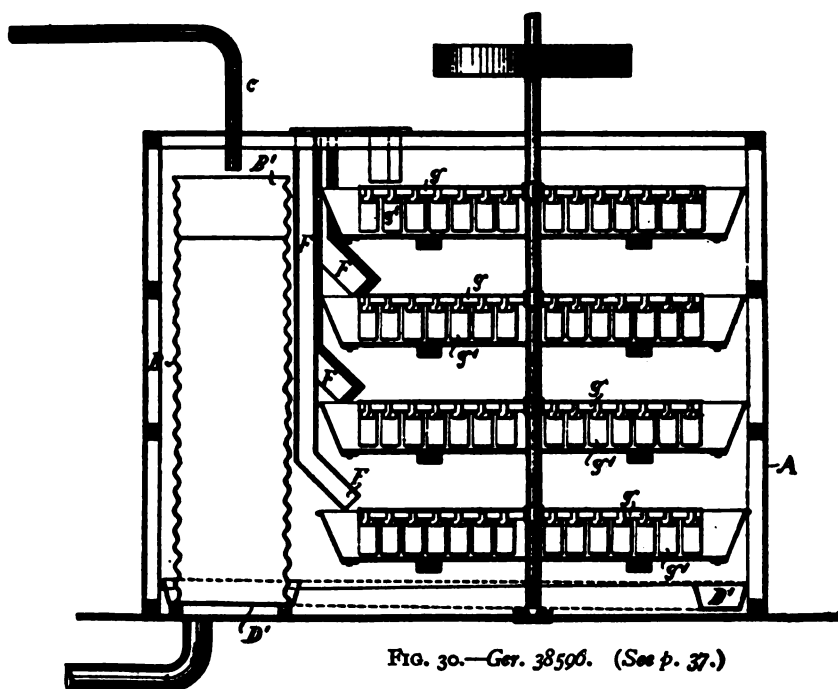


FIG. 30.—Ger. 38596. (See p. 37.)

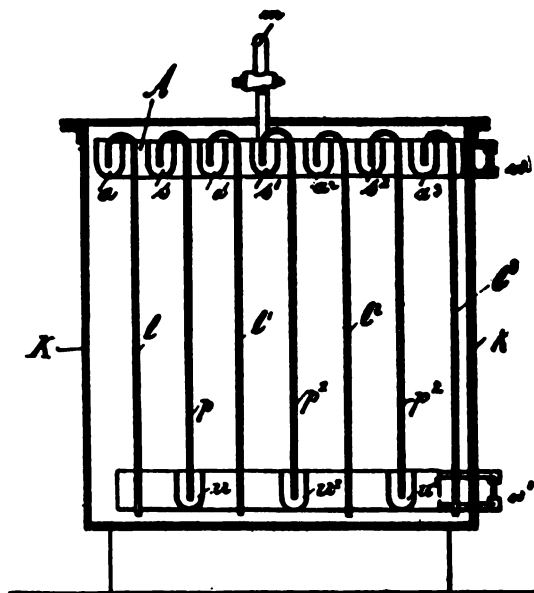


FIG. 31.—Ger. 66465.

Ger. 66465. Mylius, A. Pat. July 19, 1891; Pub. January 2, 1893.

*Title:* Apparatus for the manufacture of ammonia and other volatile nitrogenous bases from waste waters, etc.

The waste waters and sulphuric acid for absorption of the ammonia are separated by porous walls in a vessel under partial vacuum.

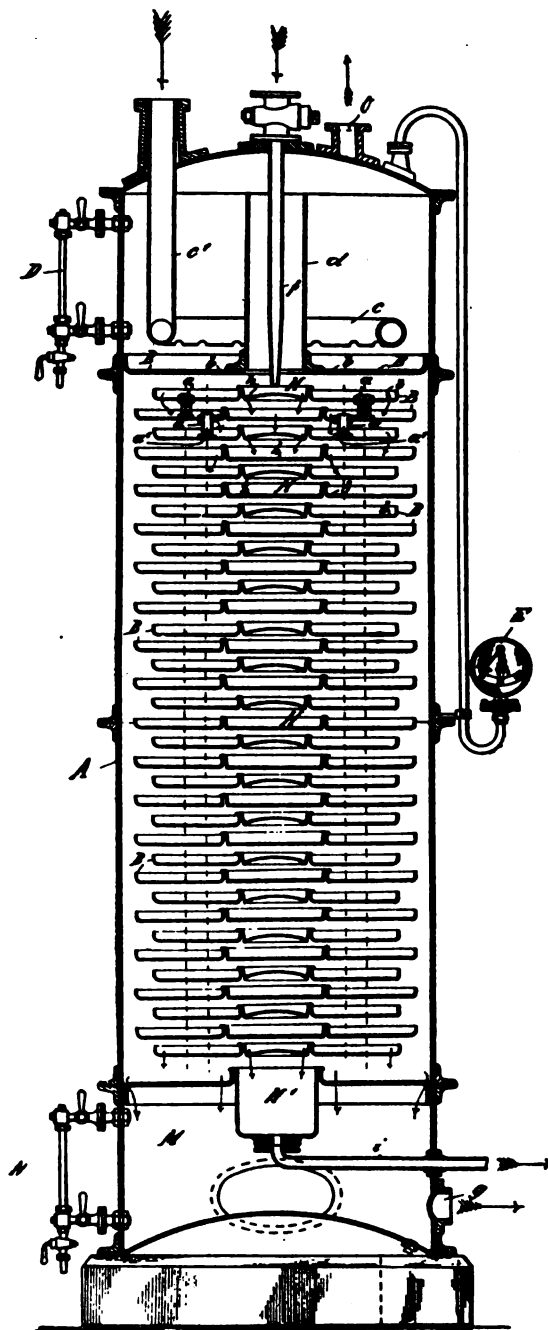


FIG. 32.—Ger. 71414.

Ger. 71414. Seiffert, H. Pat. February 3, 1893; Pub. October 10, 1893.

*Title:* Apparatus for the recovery of ammonia and other volatile nitrogen bases from waste waters, etc.

The apparatus containing the waste water under vacuum is so constructed that sulphuric acid, when added, falls over a series of plates which have sieve bottoms. The sulphuric acid binds the ammonia under the influence of the vacuum. Dilute sulphuric acid leaves by one opening, the waste water by another.

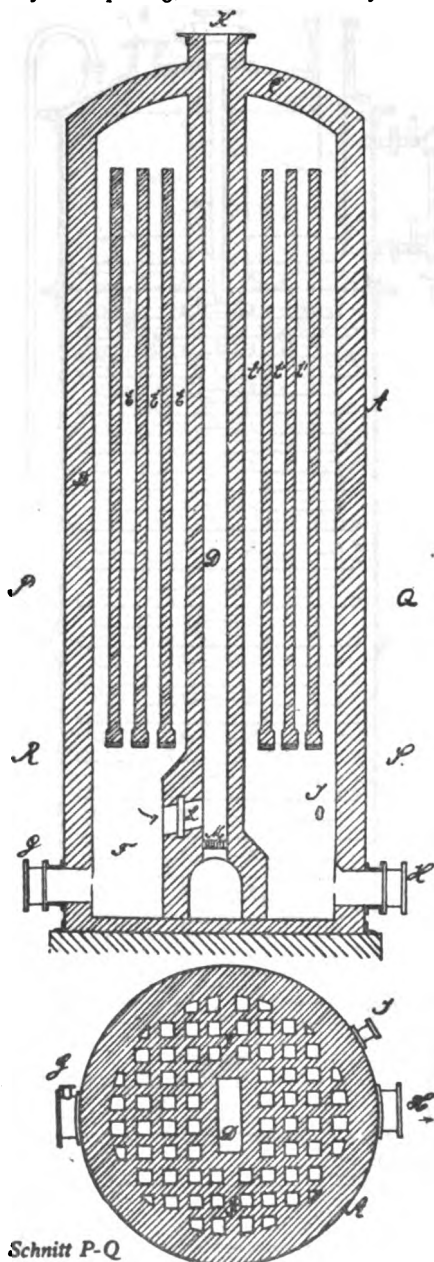


FIG. 33.—Ger. 75883.

Ger. 75883. Schulte and Sapp. Pat. August 2, 1893; Pub. July 2, 1894.

Title: Furnace for the manufacture of ammonium cyanide.

Used in the process of manufacturing ammonium cyanide from ammonia and superheated hydrocarbons. A countercurrent system of gases is used. Two ovens make the process continuous.

(d) APPARATUS FOR THE RECOVERY OF POTASH.

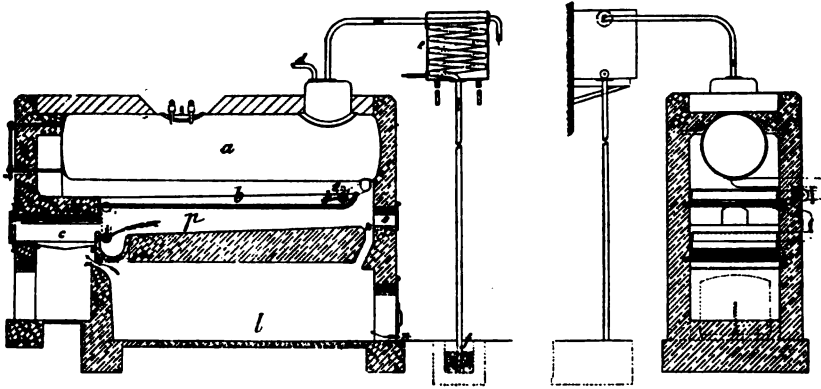


FIG. 34.—Ger. 18493.

Ger. 18493. Roeckner, C. Pat. October 22, 1881; Pub. June 24, 1882.

Ger. 27998. Lutteroth & Co. Pat. November 18, 1883; Pub. July 17, 1884.

Ger. 30724. Lutteroth & Co. Pat. January 24, 1884; Pub. April 13, 1885.

*Title:* Application of apparatus protected by patent 18493 for the recovery of soda from waste water.

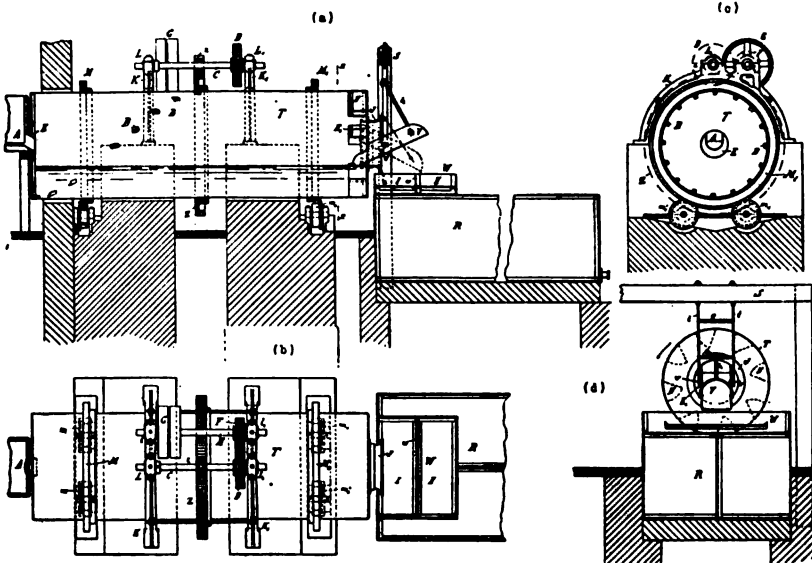


FIG. 35.—Ger. 102900.

Ger. 102900. Recht, H. Pat. June 15, 1898; Pub. May 18, 1899.

*Title:* Extraction drum for the extraction of waste-water ash.

Similar to rotating drum used in the preparation of milk of lime.

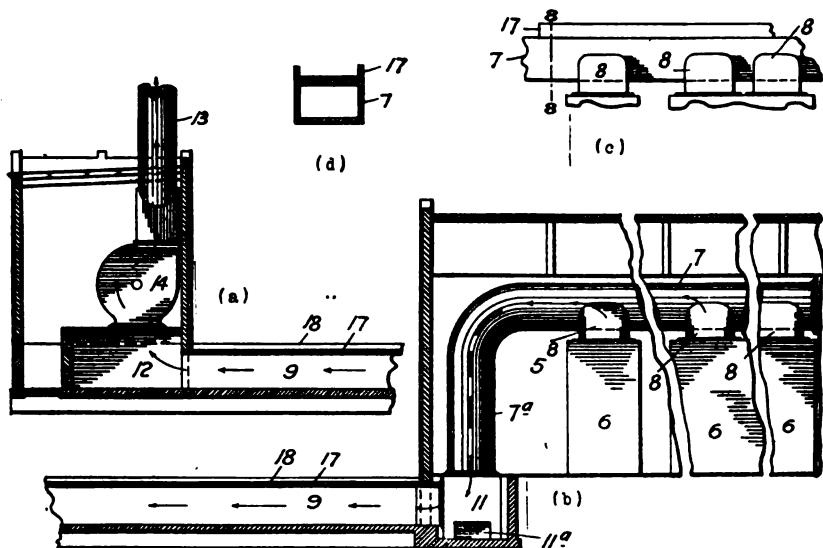


FIG. 36.—U. S. 803058.

U. S. 803058. Henry and Beale, assignors to M. Straus, Denver, Colo. App. Oct. 3, 1904. Pat. Oct. 31, 1905.

*Title:* Apparatus for extracting crude potash.

Applies to the evaporation of the lyes, which is accomplished by means of troughs built into the flues, thereby utilizing waste heat.

#### CROSS REFERENCES.

- Ger. 228539. Dieffenbach and Moldenhaver. Group 4 (c).
- Ger. 255073. Dieffenbach and Moldenhaver. Group 4 (c).
- U. S. 247046. Grouven, H. Group 2 (b).
- Fr. 353970. Guerrero, W. de Smirnoff. Group 2 (b).
- Br. 12736-7/11. Guignard and Watrigant. Group 7 (a).
- U. S. 1207416. Kochendoerfer, E. Group 4 (a).
- U. S. 846035. Koppers, H. Group 2 (c).
- U. S. 953960. Koppers, H. Group 2 (c).
- U. S. 488207. Kuntze, P. Group 2 (b).
- U. S. 232991. Lorenzen, H. P. Group 2 (b).
- Ger. 87725. Reichardt and Bueb. Group 4 (a).
- Fr. 331077. Societe F. Bruncke. Group 2 (c).

#### 4. GROUP IV.—CYANIDES.

##### (a) PRODUCTION OF CYANIDES FROM WASTE WATER DIRECT.

Ger. 86913. Reichardt and Bueb. Pat. October 25, 1894; Pub. May 2, 1896.

Br. 7171/95. Reichardt and Bueb. App. April 8, 1895; Acc. January 4, 1896.

*Title:* Process for manufacturing cyanides from waste water.

Waste water is distilled out of contact with the air and the gases led through chamotte canals raised to a red or white heat. Cyanides are formed with ammonium carbonate. The gases may be passed through a solution of iron salts to form ferrocyanides. The patentees refer to Ger. 15751 (Group 2(a)), and to the fact that Ortlieb and Mueller (Ger. 9409, Aktien-Gesellschaft Croix, Group 4(b)) were familiar with the production of cyanides from amines.

Ger. 104953. Bueb, J., and Die Dessauer Zuckerraffinerie. Pat. July 27, 1898; Pub. July 27, 1899.

U. S. 642782. Bueb, J., assignor to Roessler & Hasslacher Chemical Co. App. October 1, 1898. Pat. February 6, 1900.

Br. 26259/98. Bueb, J. App. December 12, 1898; Acc. September 30, 1899.

*Title:* Process of obtaining hydrocyanic acid from gases containing the same.

The steps in the process are as follows: (1) Separating the ammonia contained in the gases, then conducting them through alcohol of high purity and percentage, then subjecting the alcoholic solution of hydrocyanic acid to fractional distillation. (2) Gases from the fractional distillation in (1) pass through a chamber containing alcoholic caustic potash, wherein hydrocyanic acid is separated from the alcohol as an insoluble cyanide. (3) Saturating the mother liquor, which contains hydrocyanic acid, with carbon dioxide (contained in the gas mixture), whereby the alkali will be precipitated as a carbonate, while hydrocyanic acid becomes dissolved in the alcohol and may be separated therefrom.

Fr. 296793. Bueb, J. Pat. February 2, 1900.

*Title:* Process of cyanizing gases from vinasses. (Unpublished.)

Ger. 113530. Bueb, J. Pat. August 20, 1899; Pub. August 13, 1900.

*Title:* Process of manufacturing cyanogen compounds from waste water and similar gases according to patent 86913.

In the older process, the retorts became congested with carbon after a period of heating. This patent provides for alternating the ovens while this carbon deposit is burned out.

Ger. 120264. Besemfelder, E. Pat. May 19, 1900; Pub. April 30, 1901.

Br. 4323/01. Besemfelder, E. App. February 28, 1901; Acc. October 19, 1901.

*Title:* Manufacture of cyanogen compounds from gas mixtures containing ammonia.

The ammoniacal gases produced by the destructive distillation of organic nitrogenous matter are passed through a rope or chain tower fed with cold, strongly alkaline liquid, whereby ammonium salts are decomposed with the formation of ammonia. The gases are then dried by passing through scrubbers containing caustic lime before being led to the cyanizing generators. These contain incandescent coke, assumed to have been in previous use. These generators are blown hot and the gas passed through. They are arranged in series and are equipped with carbon feed and ash pits.

Ger. 181508. Chemische Fabrik Schlempe. Pat. January 17, 1906; Pub. February 16, 1907.

Fr. 367502. Chemische Fabrik Schlempe.

*Title:* Process for the manufacture of cyanogen compounds from molasses waste water.

Tar produced in the destructive distillation of waste water containing nitrogen is partially burned with access of air and passed through highly heated tubes to produce cyanogen. Also, the tar may be distilled without access to the air, mixing the resulting gases with water gas and passing through the hot tubes. Refers in the patent to Ger. 86913 and 113530.

Ger. 232615. Chemische Fabrik Schlempe. Pat. February 16, 1910; Pub. March 16, 1911.

U. S. 1032988. Bueb, J. App. October 26, 1910; Pat. July 16, 1912.

*Title:* Process for obtaining cyanogen and its compounds.

The cyanizable and noncyanizable gases from waste water distillation are separated before cyanizing; for example, by condensation, between the retort and superheater, or by counter-current scrubbing of the gases with condensate to remove all cyanizable substances. The scrubbing solution is then distilled and the gases passed into the superheater.

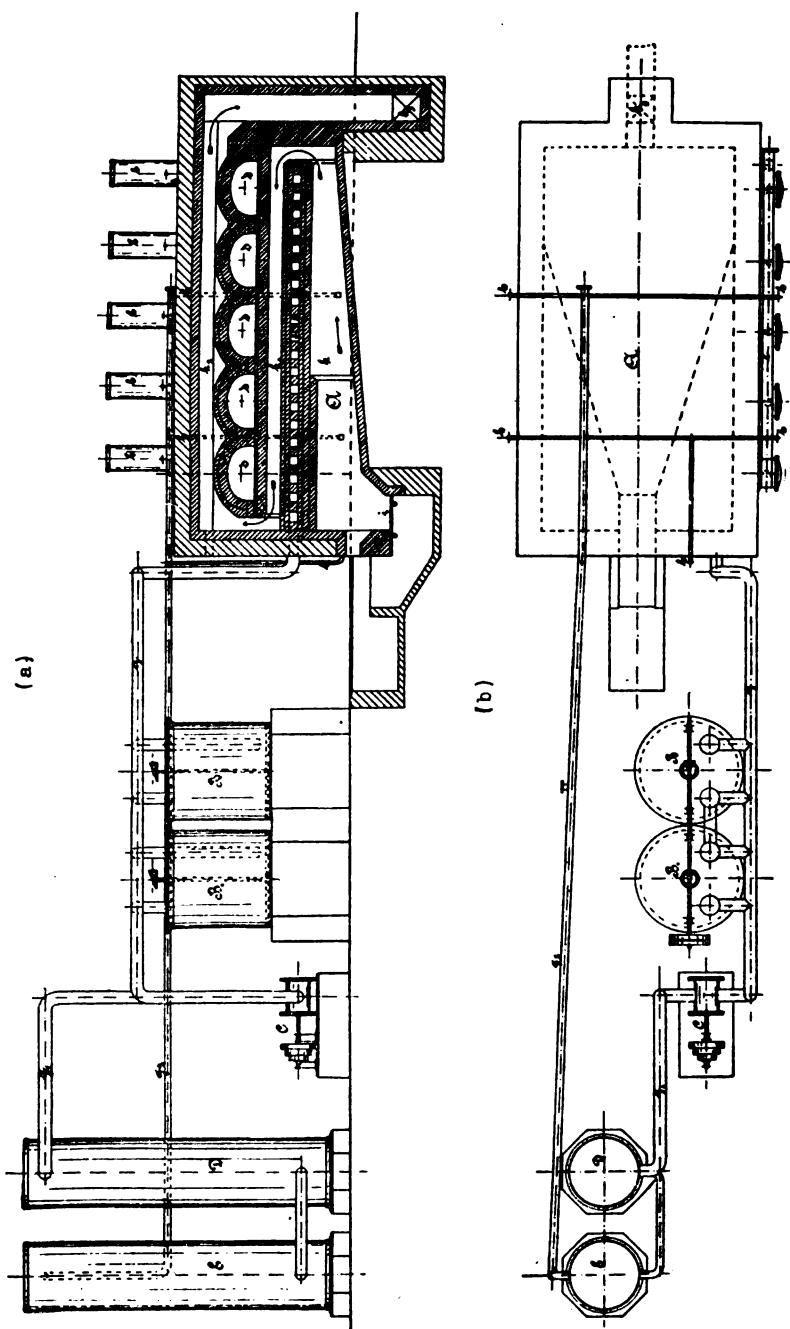


FIG. 37A.—Ger. 87725.

Ger. 87725 (addition to Ger. 86913). Reichardt and Bueb. Pat. September 29, 1895; Pub. July 18, 1896.

*Title:* Furnace for the manufacture of cyanogen compounds from waste water.

Description of the furnace used for the process described in 86913. (See p. 42.)

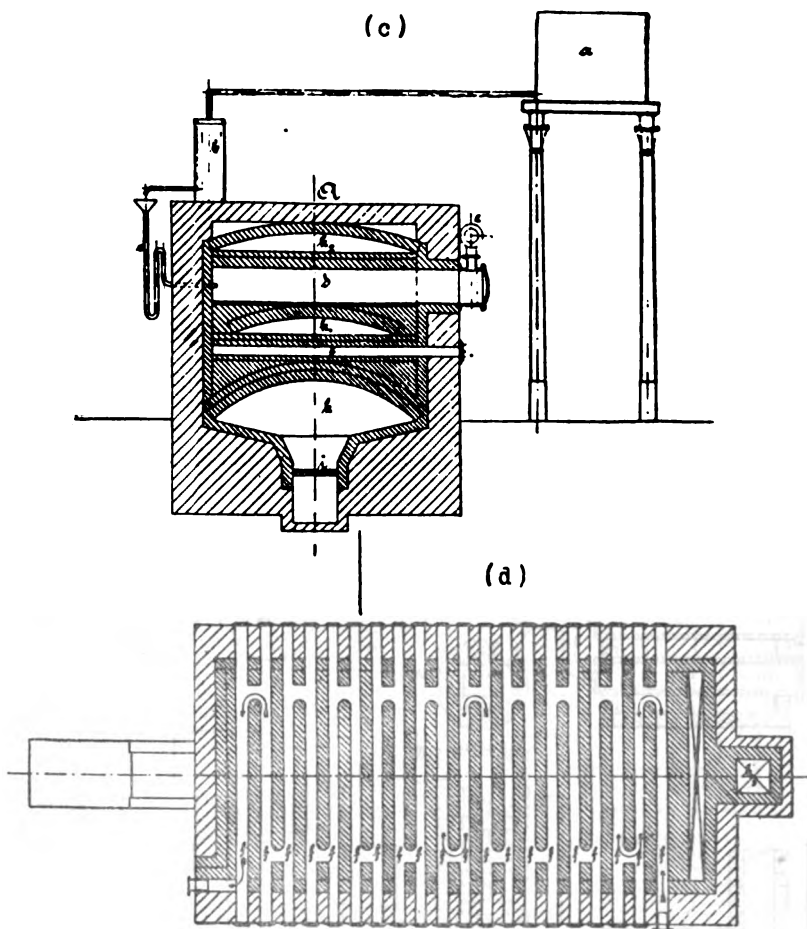


FIG. 37B.—Ger. 87725.

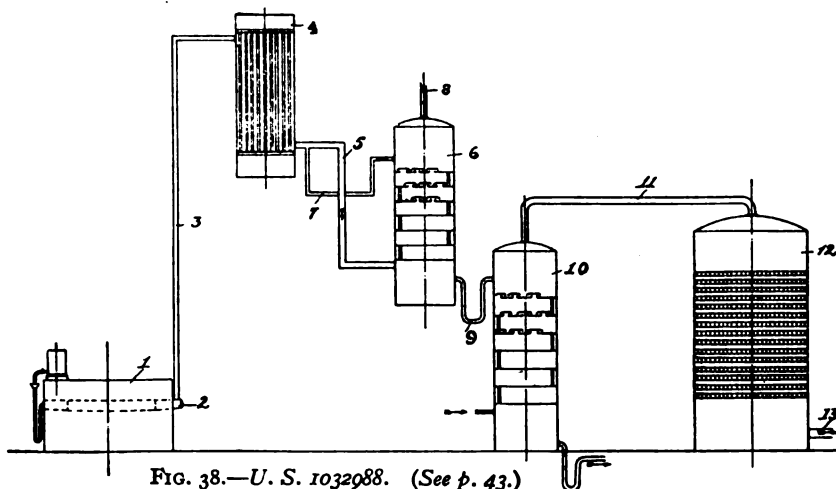


FIG. 38.—U. S. 1032988. (See p. 43.)

Ger. 255440. Deutsche Gold und Silberscheide-Anstalt. Pat. November 9, 1911; Pub. January 3, 1913.

Fr. 447725. Deutsche Gold und Silberscheide-Anstalt. App. August 29, 1912; Pat. November 5, 1912; Pub. January 13, 1913.

*Title:* Process of cyanizing gases from waste water.

The gases are superheated in chambers, free of baffling substances, by radiant heat. They are then passed through hot tubes which are smooth, thick and nonporous, such as fused quartz or a mixture of quartz and zirconia.

Ger. 259501. Deutsche Gold und Silberscheide-Anstalt. Pat. April 7, 1912; Pub. April 25, 1913.

Fr. 448722. Deutsche Gold und Silberscheide-Anstalt. App. September 5, 1912; Pat. December 4, 1912; Pub. February 8, 1913.

*Title:* Process of obtaining cyanogen from the gases from waste water or analogous substances.

Gases from the calcination of waste water are superheated in refractories of acid nature without regard to the physical properties of porosity, etc., choosing a speed of flow which will suppress the catalytic action of the surfaces. This process avoids separation of the tar formed. The gases are led directly from the retort to the superheater.

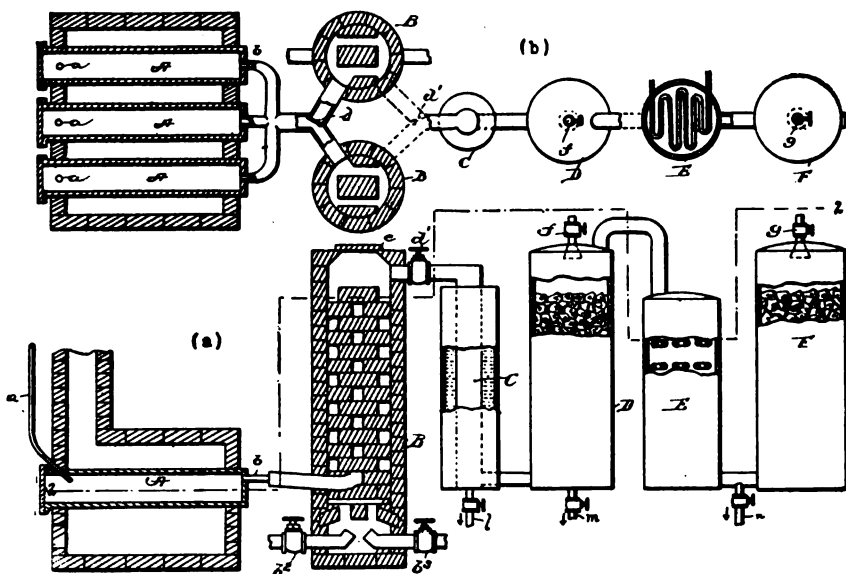


FIG. 39.—U. S. 1145484.

U. S. 1145484. Huber and Poindexter. App. July 21, 1914; Pat. July 6, 1915.

*Title:* Utilizing beet molasses waste water.

Steffen waste water is concentrated and destructively distilled in the absence of air, the gases are superheated, changing some to hydrocyanic acid. The ammonia is absorbed in sulphuric acid and the hydrocyanic acid in water. Gives the following yields: 55 per cent of nitrogen obtained as hydrocyanic acid; 26 per cent of nitrogen obtained as ammonia; and 90 per cent of potassium obtained as salts.

U. S. 1165358. Kochendoerfer, E. App. October 31, 1912; Pat. December 21, 1915.

*Title:* Process for manufacturing nitrogen compounds.

For producing cyanides from waste water superheaters are used, composed of silica, zirconia, etc., with smooth unimpeded walls and free passages. Heating is accomplished by radiation.

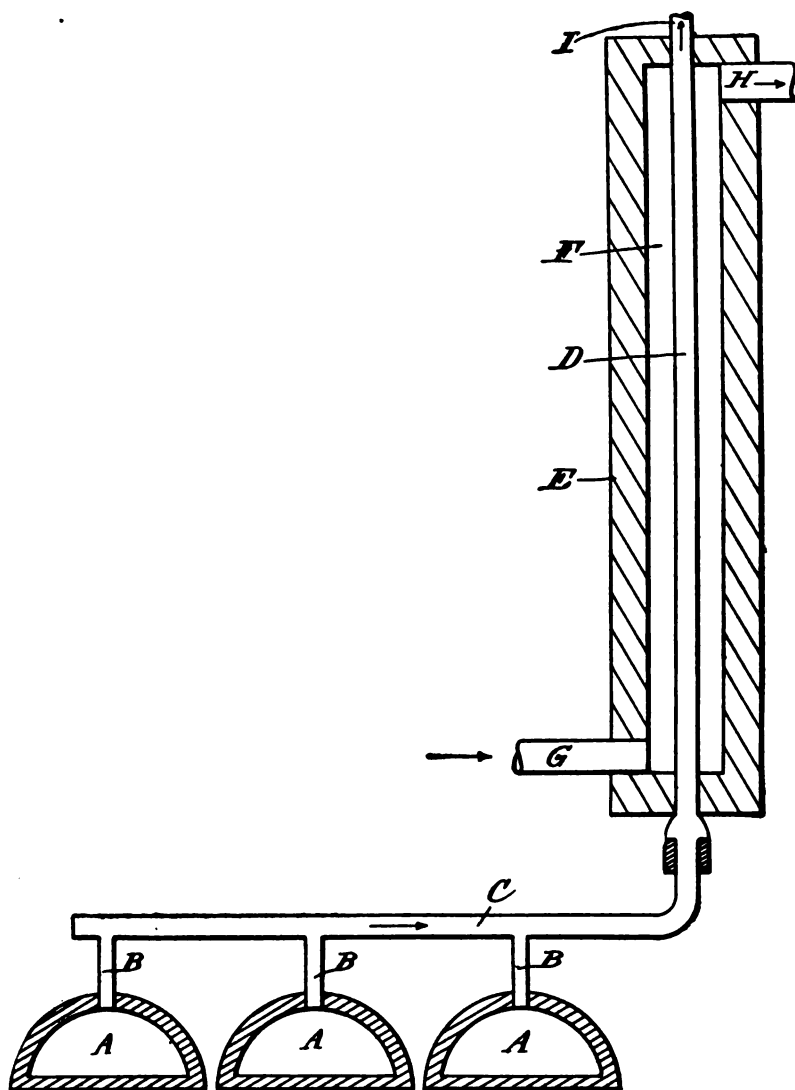


FIG. 40.—U. S. 1165358. (See p. 46.)

U. S. 1207416. Kochendoerfer, E. App. March 26, 1913; Pat. December 5, 1916.

*Title:* Process of manufacturing nitrogen compounds.

The patent claims that for producing cyanides from waste water, rough or porous surfaces are deleterious; claims use of high speed of gases in superheating; for example, 7 m. per second for pyridines; 10 m. per second for amino compounds. It is necessary to use material of an acid nature for the superheaters, for instance, Dinas stone (chiefly quartz), but basic materials may also be used if the speed is high enough. The distillation gases from waste water incineration are used directly without separation of the inactive constituents.

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## (b) PRODUCTION OF CYANIDES FROM AMINES BY SPECIAL PROCESSES.

Br. 3844/79. Societe Anonyme de Croix and Imbray, J. App. September 24, 1879; Acc. March 5, 1880.

*Title:* Manufacture of hydrocyanic acid, etc.

The methylamine of commerce is vaporized and the vapors passed through a retort heated to redness, the products being absorbed in sodium or potassium hydroxide and the ammonia in acid. The methylamine vapors may also be passed into molten potassium hydroxide.

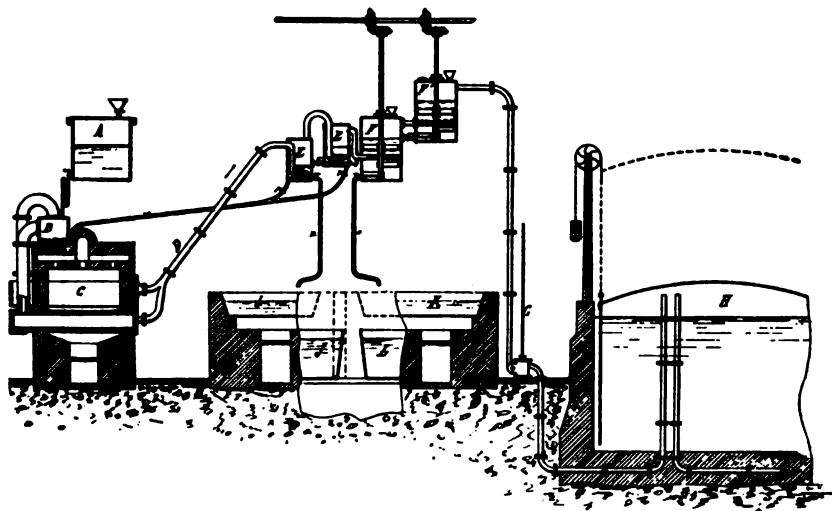


FIG. 41.—Ger. 9409.

Ger. 9409. Aktien-Gesellschaft Croix. Pat. September 27, 1879; Pub. April 5, 1880.

*Title:* Improved process of manufacturing hydrocyanic acid and its derivatives from trimethylamine.

This patent covers the original Ortlieb and Mueller process for the production of hydrocyanic acid. If gaseous trimethylamine is led through glowing vessels, great quantities of hydrocyanic acid are formed, as well as ammonia and fuel gas.

U. S. 967943. Liebknecht, O., assignor to Roessler & Hasslacher Chemical Co. App. April 16, 1910; Pat., August 23, 1910.

U. S. 969885. Liebknecht, O., assignor to Roessler & Hasslacher Chemical Co. App. February 28, 1910; Pat. September 13, 1910.

Br. 9375/10. Deutsche Gold und Silberscheide-Anstalt. App. April 18, 1910; Acc. October 27, 1910.

*Title:* Improvements in the manufacture of sodium cyanide.

Trimethylamine may be directly decomposed with the formation of sodium cyanide by passing the dry gas through molten metallic sodium. A hydrocarbon, carbon and hydrogen being formed at the same time. The sodium cyanide may be separated from the carbon by filtration, or the formation of carbon may be avoided by the addition of disodium cyanamide, or by allowing ammonia to pass into the fused metallic sodium along with the trimethylamine. The temperature of the molten sodium should be about 700° C.

## (c) PRODUCTION OF CYANIDES FROM VARIOUS GAS MIXTURES.

Br. 3735/93. de Lambilly, P. R. App. February 20, 1893; Acc. November 11, 1893.

*Title:* An improved method of producing ammonium formate from ammonia and from this, hydrocyanic acid.

A mixture of carbon monoxide and ammonia passed over a porous substance at 100–130° C. produces ammonium formate, which, when passed through a set of tubes at 210° C. in which is more porous substance forms hydrocyanic acid and water.

Br. 26236/97. Lance and Bourgade. App. November 11, 1897; Acc. July 2, 1898.

*Title:* A Process for the economic production of cyanides, their derivatives and other nitrogen compounds.

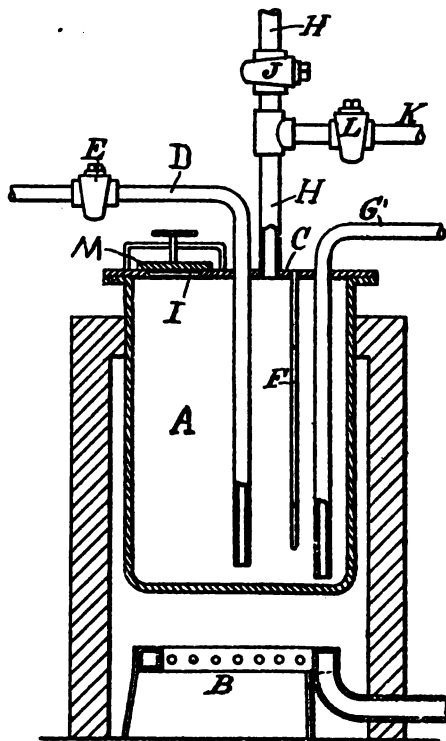


FIG. 42.—U. S. 969885. (See p. 48.)

On passing a mixture of nitrogen, hydrogen, and ammonia over intensely heated carbon, ammonium cyanide is formed and volatilized. To obtain the maximum yield, an excess of hydrogen must be used. Instead of pure hydrogen, hydrocarbons may be used which are obtained from the distillation of organic matter, and nitrogen as in the air. A typical mixture is 2,000 l. of hydrocarbon, 200 l. of nitrogen, and 80 l. of ammonia passed through carbon heated to 1,100° C. The ammonium cyanide is absorbed by an alcohol washer. Sodium or potassium cyanide may be obtained by treating with an alcoholic solution of soda or potash.

Br. 19804/02. Wolterreck, H. C. App. September 10, 1902; Acc. September 10, 1903.

*Title:* Process for producing hydrocyanic acid.

Perfectly dry ammonia and a volatilized or gaseous carbon compound, also perfectly dry, are passed together with hydrogen in equal volumes, over a strongly heated catalytic agent, such as platinized pumice. One volume of ammonia and two volumes of water gas make a convenient mixture. The hydrocyanic acid is absorbed, preferably in an alkaline solution.

Ger. 29057. Dieffenbach and Moldenhaver. Pat. June 12, 1908; Pub. November 28, 1910.

U. S. 954080. Dieffenbach and Moldenhaver. App. April 16, 1908; Pat. April 5, 1910.  
*Title:* Process for producing hydrocyanic acid.

Hydrocyanic acid is produced by passing a mixture of hydrogen, nitrogen, and not over 40 per cent carbon monoxide or dioxide over highly heated coal.

Ger. 228539. Dieffenbach and Moldenhaver. Pat. February 27, 1908; Pub. November 10, 1910.

Ger. 255073 (addition to Ger. 228539). Dieffenbach and Moldenhaver. Pat. July 4, 1911; Pub. December 27, 1912.

*Title:* Hydrocyanic acid from nitrogen and hydrocarbons in an electric arc.

Gases are passed through a resistance furnace, composed of a coke floor with adjustable electrodes. Provision is made for the introduction of fresh coke, thereby making the process continuous.

Br. 18945/09. Beindl, C. App. August 17, 1909; Acc. August 17, 1910.

U. S. 1144457. Beindl, C. App. September 1, 1910; Pat. June 29, 1915.

*Title:* Method of producing cyanogen compounds.

Cyanides are obtained from ammonia and volatile or gaseous carbide by passing the mixture over a catalyser in the form of wire net, heated to the appropriate temperature, of one of the following substances: Gold, silver, iridium, palladium, rhodium, copper, manganese, cobalt, nickel, iron, chromium, and their nitrides; also such alloys as copper-zinc. The gases used must be pure and dry. For example, ammonia and acetylene passed over copper forms hydrocyanic acid at about 480° C.

Br. 7260/15. Beindl, C. App. May 14, 1915; Acc. August 16, 1917.

Br. 10321/15. Beindl, C. App. July 15, 1915; Acc. July 11, 1921.

*Title:* An improved process for the production of hydrocyanic acid.

Specifies, in addition to the catalysts given in Br. 18945/09, etc., the following: Nitrides of the ores of molybdenum, uranium, tungsten, osmium, titanium, and possibly the oxides, produced at a temperature of 700° C.

Ger. 232878. Hauff. Pat. August 3, 1910; Pub. March 25, 1911.

*Title:* Process for changing hydrocyanic acid to ammonia.

Gases containing hydrocyanic acid are mixed with steam as they come from the electric furnace (at 1,000–1,300° C.), and the current of gas is passed through a bundle of tubes of fire-resisting porcelain or the like which is maintained at the proper temperature.

U. S. 1387170. Poindexter, R. W. App. July 6, 1920; Pat. August 9, 1921.

*Title:* Process of producing hydrocyanic acid.

The process consists of heating a hydrocarbon and injecting ammonia into it, further heating to cause reaction, above 500° C., and again heating to 1,000° C. The upper limit is specified as 1,450° C.

#### (d) RECOVERY OF HYDROCYANIC ACID FROM GAS MIXTURES.

Br. 1608/08. Percy and Byrom. App. January 23, 1908; Acc. December 17, 1908.

*Title:* Improvements in obtaining or extracting hydrocyanic acid from waste gases.

Hydrocyanic acid is recovered by a counter-current washing in a tower with a trickle of water so as not to absorb sulphur. The sulphur may be precipitated with lead, and the hydrocyanic acid recovered as usual by distillation.

Ger. 243469. Guignard and Watrigant. Pat. January 21, 1911; Pub. February 13, 1912.

Fr. 436185. Guignard and Watrigant. App. January 16, 1911; Pat. January 17, 1912; Pub. March 20, 1912.

*Title:* Process of recovery of hydrocyanic acid contained in a gas.

Hydrocyanic acid may be absorbed in a solution of an alkali dissolved in alcohol, and destroying, eliminating, or absorbing the water formed in the reaction. This may be done by adding from time to time metallic sodium.

Fr. Addition No. 15080. Guignard and Watrigant. Pat. February 10, 1911.

The alcohol in the above patent specification may be replaced with glycerine.

In addition to the patents listed above, the reader is also referred to the many patents wherein the methods of recovery of the hydrocyanic acid are incorporated with the other details of the process, as in the preceding subgroups.

(c) PREPARATION OF CYANIDES IN MARKETABLE FORM.

U. S. 716350. Roessler, F., assignor to Roessler & Hasslacher Chemical Co. App. February 4, 1899; Pat. December 16, 1902.

*Title:* Method of making sodium cyanide.

The absorbing caustic solution is maintained at a temperature above 33° C., for instance, at 50° C., so that anhydrous sodium cyanide is precipitated when the concentration of sodium cyanide becomes greater than 517 g. per liter.

Ger. 192884. Chemische Fabrik Schlempe. Pat. August 28, 1906; Pub. December 14, 1907.

U. S. 859482. Bueb, J., assignor to Roessler & Hasslacher Chemical Co. App. March 19, 1907; Pat. July 9, 1907.

*Title:* Cyanide briquet and process for making same.

The cyanide is melted and free caustic hydroxide is added. Both crystallize together and are dried and briquetted.

Ger. 194446. Chemische Fabrik Schlempe. Pat. April 27, 1907; Pub. January 20, 1908.

U. S. 912538. Bueb, J., assignor to Roessler & Hasslacher Chemical Co. App. April 15, 1908; Pat. February 16, 1909.

*Title:* Process of making cyanide briquets.

After briquetting alkali cyanides they are allowed to stand for several hours in a closed room under a high vacuum at a temperature of 70° C., thereby driving off the moisture without decomposing the cyanide.

U. S. 1232471. Abegg, F., assignor to Roessler & Hasslacher Chemical Co. App. June 23, 1914; Pat. July 10, 1917.

*Title:* Cyanide in the form of granules.

Molten cyanide is projected in a thin jet against a plate so as to form hollow droplets (most of which are open at one end) when solidified, and glazed both inside and outside.

U. S. 1262057. Kaufmann, A., assignor to Air Reduction Co. App. November 7, 1916; Pat. April 9, 1918.

*Title:* Sodium cyanide briquet.

Granular sodium cyanide or the like is compressed into a briquet with two oppositely placed indentures to facilitate breaking and with two supporting ribs to provide free space about the briquet. The briquet thus formed is passed through a suitable furnace to fuse the outer surface, thus providing a protective coating. The patent claims easy solubility by reason of the inner granular condition, and high resistance to absorption of water and carbon dioxide by reason of the protective coating.

CROSS REFERENCES.

Fr. 59268. Evrard. Group 7 (d).

Ger. 339302. Muhlert. Group 2 (a).

## 5. GROUP V.—NITROGENOUS NONSUGARS.

## (a) BETAINE AND GLUTAMINIC ACID FROM WASTE WATER AND MOLASSES.

Fr. 344954. Stiepel, C. App. July 19, 1904; Pat. September 23, 1904; Pub. November 18, 1904.

Ger. 157173. Stiepel, C. Pat. March 4, 1904; Pub. December 9, 1904.

Br. 15934/04. Stiepel, C. App. July 18, 1904; Acc. May 18, 1905.

*Title:* Process for extracting betaine or its salts from molasses.

Concentrated molasses is mixed with twice its volume of 95 per cent alcohol. The mixture is allowed to settle, the alcoholic layer decanted off, filtered, and decolorized with animal charcoal. It is concentrated to a syrup and treated with strong hydrochloric acid and cooled. Crystals of betaine hydrochloride which separate out are purified by recrystallization from alcohol.

Ger. 243332. Stolzenberg, H. Pat. May 17, 1911; Pub. February 13, 1912.

Fr. 443909. Stolzenberg, H. App. May 14, 1912; Pat. July 25, 1912; Pub. October 5, 1912.

*Title:* Process of manufacture of betaine hydrochloride from molasses, waste water and other residues of beet-sugar manufacture.

In the production of betaine hydrochloride from molasses and other waste from beet-sugar manufacture, the initial material is saturated with gaseous hydrochloric acid, the humus substances resulting from the decomposition of the sugar are filtered off from the hydrochloric-acid solution, which is allowed to stand in the cold. The precipitated alkali chlorides and the glutaminic acid hydrochloride are separated from the betaine hydrochloride remaining in the solution, the solution is evaporated in vacuo to a sirupy consistency and alcohol is added.

Ger. 280824. Melasseschlempe Gesellschaft. Pat. December 18, 1912; Pub. November 28, 1914.

*Title:* Manufacture of glutaminic acid and alkali chlorides from molasses waste water, molasses, or other residuals of beet-sugar manufacture.

After the recovery of betaine, according to Ger. 243332, the glutaminic acid is recovered in the residue. The mixture of chlorides is treated with alcohol, then gaseous hydrochloric acid. Glutaminic acid hydrochloride forms, which is very soluble. The alkali chlorides are insoluble in alcohol and are filtered off and the residual liquor evaporated and saponified by boiling with water. Further evaporation gives the glutaminic acid, which may be further purified.

Ger. 264390. Hofmann, LaRoche & Co. Pat. February 22, 1913; Pub. September 13, 1913.

*Title:* Process for the manufacture of an iron salt of glutaminic acid.

When aqueous solutions of glutaminic acid are heated with metallic iron, air being excluded, ferrous salts of glutaminic acid are obtained. Aqueous glutaminic acid solutions have no action on ferric oxide or sulphide.

Ger. 276489. Aktien Gesellschaft fur Anilin Fabrikation. Pat. May 8, 1913; Pub. July 10, 1914.

Br. 2813/13. Aktien Gesellschaft fur Anilin Fabrikation. App. May 7, 1913; Acc. April 23, 1914.

Br. 2923/13. Aktien Gesellschaft fur Anilin Fabrikation. App. October 16, 1913; Acc. June 4, 1914.

Fr. 468366. Aktien Gesellschaft fur Anilin Fabrikation. App. February 12, 1914; Pat. April 22, 1914; Pub. July 4, 1914.

U. S. 1219226. Bergami and Saemann, assignors to Aktien Gesellschaft fur Anilin Fabrikation. App. March 4, 1914; Pat. March 13, 1917.

*Title:* Process for the manufacture of betaine from vinasses.

Crude betaine hydrochloride is obtained by treating a vinasse, nearly dehydrated by evaporation in a vacuum, with sufficient hydrochloric acid to produce a strongly acid reaction to Congo indicator, keeping the temperature below 60° C., cooling, filtering, and washing the crystals obtained with a little alcohol, and drying. On recrystallizing from methyl alcohol, a product of 95 per cent purity may be obtained, which may be converted into white betaine hydrochloride by crystallizing from water in the presence of animal charcoal. By using hydrobromic or hydriodic acids instead of hydrochloric, the corresponding bromide or iodide may be obtained.

Fr. 483313. Corti, A. App. October 31, 1916; Pat. March 26, 1917; Pub. June 26, 1917.

*Title:* Process for separating glutaminic acid from other amino acids.

Excess of free hydrochloric acid prevents glutaminic acid from precipitation. The acid solution is cooled and exactly neutralized. Glutaminic acid is 1 per cent soluble. It crystallizes in fine grain, and is then recrystallized. An example is given of its preparation from wheat gluten. Other amino acids are left in the mother liquors.

#### (b) BETAINE PREPARED FROM OTHER SOURCES.

Ger. 269701. Aktien Gesellschaft fur Anilin Fabrikation. Pat. October 25, 1912; Pub. January 28, 1914.

Br. 15162/13. Aktien Gesellschaft fur Anilin Fabrikation. App. July 1, 1913; Acc. September 11, 1913.

*Title:* Process for manufacturing betaine and its salts.

A quantitative yield of betaine is said to be obtained by the action of trimethylamine on an alkali salt of monochloroacetic acid, preferably in aqueous solution and under pressure. The product may be evaporated to dryness and the betaine extracted from the residue by means of absolute alcohol. To prepare a salt of betaine, the necessary acid is added to the liquid before or during evaporation.

Ger. 269751. Aktien Gesellschaft fur Anilin Fabrikation. Pat. October 17, 1912; Pub. January 30, 1914.

Br. 15161/13. Aktien Gesellschaft fur Anilin Fabrikation. App. July 1, 1913; Acc. August 28, 1913.

Fr. 459561. Aktien Gesellschaft fur Anilin Fabrikation. App. July 21, 1913; Pat. September 10, 1913; Pub. November 8, 1913.

Br. 16710/13. Aktien Gesellschaft fur Anilin Fabrikation. App. July 21, 1913; Acc. September 4, 1913.

*Title:* Process for making betaine hydrochloride.

The hydrochloride of the methyl ester of aminoacetic acid is converted into betaine hydrochloride by heating with methyl alcohol. Other derivatives of aminoacetic acid may be used, followed by saponification.

#### 6. GROUP VI.—POTASH AND ALKALI SALTS.

Fr. 167119. Lesage-Montagne. Pat. February 21, 1885.

*Title:* Leaching and exhausting salts from beets and potash from wool fat. (Unpublished.)

Ger. 77182. Societe Wache Locoge et Cie. Pat. September 1, 1893; Pub. October 10, 1894.

*Title:* Process of refining beet potash.

Process adapted for French potash lyes. The raw potash is leached with a concentrated solution of potassium sulphate or chloride, depending upon which salt predominates.

Ger. 88003. Graff, W. Pat. February 23, 1896; Pub. July 22, 1896.

*Title:* Separation of sodium hydroxide from solutions of potassium and sodium hydroxides as potassium sodium carbonate.

Sufficient concentrated solution of potassium carbonate is added to a solution containing potassium and sodium hydroxides to form a double salt, which separates in crystals upon evaporation. A solution of waste-water ash is made caustic with lime, evaporated to 50° B. to separate potassium sulphate and potassium chloride, and then freed in the above manner from sodium hydroxide.

Ger. 91730. Graff, W. Pat. October 31, 1896; Pub. April 3, 1897.

*Title:* Separation of sodium hydroxide from solutions of potassium and sodium hydroxides as potassium sodium carbonate.

The solution from the main patent, No. 88003, already contains potassium carbonate and sodium hydroxide. This is evaporated almost to dryness to separate potassium sodium carbonate from lime. The residue is extracted with alcohol which dissolves potassium hydroxide, and the potassium sodium carbonate remains behind.

Fr. 312562. Savary. Pat. July 6, 1901.

*Title:* New process for the treatment of molasses vinasses for the extraction of potassium salts and glycerine, and the utilization of nitrogen. (Unpublished.)

Ger. 191105. Bauer, E. Pat. December 4, 1906; Pub. November 9, 1907.

Fr. 372415. Bauer, E. App. December 11, 1906; Pat. February 18, 1907; Pub. April 6, 1907.

*Title:* Process of manufacture of a high-percentage technically pure potash salt from beet-sugar waste salts.

Potash of high percentage is obtained by purifying the liquors, concentrating to 58–62° B., raising the temperature above 90° C., when potassium sodium carbonate, which contains nearly all the soda, separates. This precipitate is separated. The remaining liquor is heated to 90° C. and cooled to about 50° C. when a new precipitate is formed, which is separated, and the sodium chloride, containing potassium chloride, is diluted to 52° B. and cooled to precipitate potassium chloride.

Ger. 210273. Grun, E. Pat. November 10, 1906; Pub. May 25, 1909.

*Title:* Process of manufacture of high-percentage potash from beet-sugar waste ash.

Carbon dioxide is passed through the lye (40° B.) at a temperature of 40–50° C. after the by-products have been partially removed therefrom. The carbon dioxide is used under pressure. At 39° B. the carbon dioxide is cut out and the potassium carbonate removed and the lye concentrated. The sodium bicarbonate in the lye is changed to sodium carbonate by heating. Carbon dioxide is again passed through the lye and more potassium carbonate is recovered.

Fr. 385139. Riviere, L. App. February 28, 1907; Pat. February 29, 1908; Pub. May 2, 1908.

Fr. Addition No. 8702. Riviere, L. App. March 28, 1907; Pat. March 30, 1908; Pub. June 12, 1908.

Fr. Addition No. 8908. Riviere, L. App. May 11, 1907; Pat. May 12, 1908; Pub. July 24, 1908.

Fr. Addition No. 9228. Riviere, L. App. July 1, 1907; Pat. July 8, 1908; Pub. September 17, 1908.

*Title:* Manufacture of depotassiumized molasses. Industrial use of these products.

This elaborate process includes treatment of vinasse for extraction of ammonia and its salts, glycerine, and a solid residue. The steps and apparatus outlined are as follows: (1) Apparatus for the preparation and regeneration of hydrofluosilicic acid (used to precipitate the potassium). (2) Apparatus for the precipitation of potassium and sodium, and, if needed, for the extraction of ammoniacal nitrogen before fermentation. (3) Fermentation and distillation of the depotassiumized molasses.

Ital. 135224. Vigano and Soldi. Pat. August 12, 1913.

*Title:* Obtaining ammonia and potash from molasses slop.

After the extraction of the alcohol from the molasses, the residual liquor is treated in a furnace, whereby a residue rich in potassium salts is obtained. This mass, after being drawn from the furnace in an incandescent state, is burned further "in pleno," cooled and crushed for the market. The nitrogen still contained in the furnace may be utilized by means of a circulation of air and water vapor with condensation of the resulting ammonium hydroxide, or the ammonia may be absorbed in sulphuric acid.

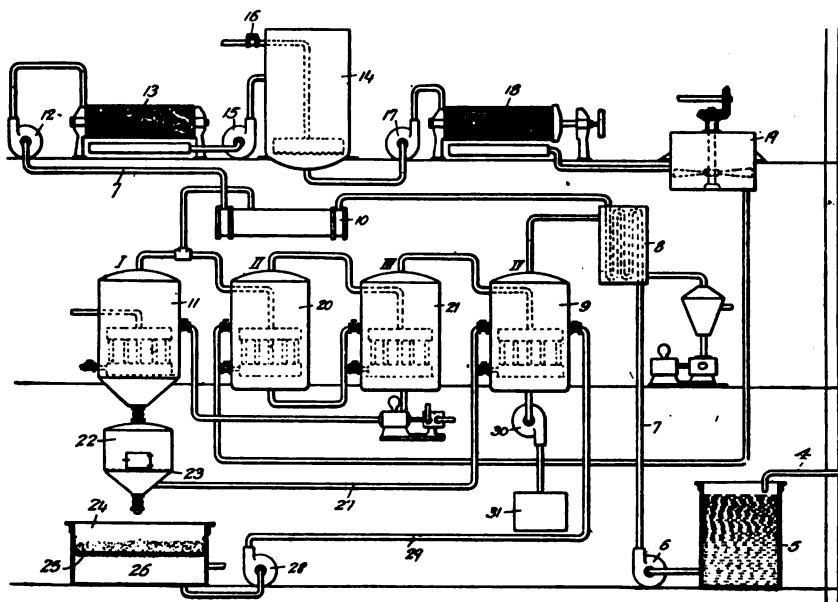


FIG. 43.—U. S. 1303916.

U. S. 1303916. Kermer and Faber. App. March 15, 1918; Pat. May 20, 1919.

*Title:* Method of reclaiming potassium salts, etc., from sugar refuse.

Waste water is heated to 185° F. and carbon dioxide added, then filtered. Sulphuric acid (0.2 per cent by weight) is added to precipitate the impurities and form soluble sulphates. The liquor is then evaporated until potassium sulphate begins to crystallize and subsequently dried to obtain nitrates in the residue.

U. S. 1376662. Whitaker, M. C., assignor to U. S. Industrial Alcohol Co. App. November 12, 1918; Pat. May 3, 1921.

*Title:* Process for obtaining alcohol and potassium compounds.

Cane molasses, diluted, is fermented in the presence of hydrofluosilicic acid in quantity insufficient to precipitate all the potassium salts in solution, using a yeast accustomed to the acid. After the alcohol is distilled sufficient acid is added to precipitate all the potassium salts. Sulphuric acid is added and the hydrofluosilicic acid may be recovered, while potassium sulphate may be purified by solution in water and recrystallizing.

U. S. 1400192. Whitaker, M. C., assignor to U. S. Industrial Alcohol Co. App. December 31, 1917; Pat. December 13, 1921.

*Title:* Process of obtaining potassium compounds.

Similar to the preceding patent, but adds the recovery of the hydrofluosilicic acid in the following manner: The acid is recovered from the potassium salt thereof by

the addition of another acid, distilling and absorbing the evolved gas in distillery waste, thus precipitating more potassium salts, introducing sufficient additional hydrofluosilicic acid to compensate for the loss thereof in the process, and then recovering the latter from the precipitate in the same manner.

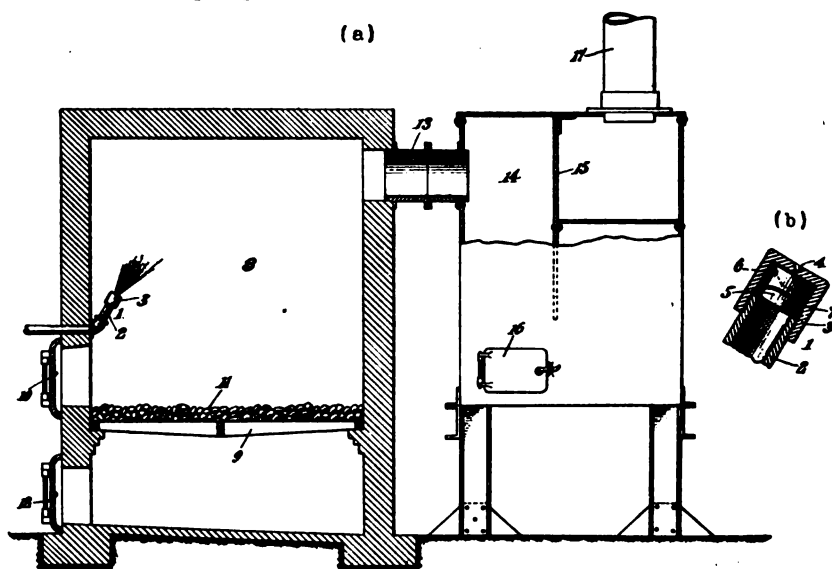


FIG. 44.—U. S. 1403160.

U. S. 1403160. Haner, C., assignor to U. S. Industrial Alcohol Co. App. February 19, 1920; Pat. January 10, 1922.

*Title:* Process of obtaining potash from distillery waste by burning the same.

Distillery slop or waste is sprayed into a combustion chamber to effect desiccation and obtain mixed potassium salts adapted for use as a fertilizer.

#### CROSS REFERENCES.

U. S. 1344850-1. Bassett. Group 7 (a).

Fr. 59268. Evrard. Group 7 (d).

U. S. 1145484. Huber and Poindexter. Group 4 (a).

Fr. 447138. Riviere, L. Group 7 (a).

U. S. 486647. Sternberg, L. Group 2 (a).

Ger. 78442. Sternberg, L. Group 2 (a).

### 7. GROUP VII.—RECOVERY OF MISCELLANEOUS PRODUCTS FROM MOLASSES, WASTE WATER, DISTILLERY SLOP, ETC.

#### (a) GLYCERINE, FATTY ACIDS, ESTERS, ETC.

Fr. 150999. Dehaut. Pat. September 7, 1882.

*Title:* Extraction of glycerine from vinasses from all sources. (Unpublished.)

Fr. 166948. Prenez. Pat. February 10, 1885.

*Title:* Extraction of glycerine from distillery vinasses. (Unpublished.)

Fr. 362654. Riviere, L. App. January 23, 1906; Pat. April 11, 1906; Pub. July 4, 1906.

*Title:* Apparatus and process for treating distillery by-products.

The apparatus and process described are for the treatment of distillery residues, such as those which are freed from the greater part of their potash by precipitation

(by means of 40-45 per cent hydrofluosilicic acid) on leaving the stills, and returned with as small a loss as possible, either to the diffusors or to the mash tuns, or, after utilizing the heat, to the drains. The process permits of recovery of the ammonia by distillation in autoclaves, evaporation and extraction of the residue for glycerine, and finally recovery of the alcohol.

Fr. 417950. Lederer, A. and E. App. June 8, 1910; Pat. September 15, 1910; Pub. November 25, 1910.

Fr. Addition No. 14315. Lederer, A. and E. App. May 24, 1911; Pat. August 22, 1911; Pub. November 17, 1911.

*Title:* Process of treatment of distillery vinasse.

Vinasses are repeatedly dried on an absorbent body, such as lignocellulose until a sufficient concentration has been built up. This is extracted with alcohol and the residue briquetted and treated in much the same manner as in the Meunier patents.

Br. 12207/11. Meunier, G. App. May 20, 1911; Acc. May 20, 1912.

Br. 13018/11. Meunier, G. App. May 30, 1911; Acc. May 30, 1912.

U. S. 1107175. Meunier, G. App. May 17, 1911; Pat. August 11, 1914.

*Title:* Method and apparatus for treating distillery wash.

In order to extract glycerine, succinic acid, and other useful products from vinasse, the latter is mixed with cellulose (preferably wood cellulose) which has been completely or partially carbonized with sulphuric acid, and the mixture is dried and extracted with suitable solvents, such as crude alcohol, aided by pressure or osmosis if necessary. The residue left after extraction may be molded into briquets and burnt, whereby alkaline salts or crude pearl ash is obtained; or, it may be subjected to dry distillation to obtain methyl alcohol, acetic acid, and other products. The coke from the distillation contains oxalic acid and cyanides, and after extraction of these by lixiviation, the residue may be used as a fuel or converted into a filtering material. The crude glycerine may be purified by further treatment with carbonized cellulose.

Ger. 253573. Guignard and Watrigant. Pat. May 27, 1911; Pub. Nov. 12, 1912.

Br. 12737/11. Guignard and Watrigant. App. May 26, 1911; Acc. December 21, 1911.

*Title:* Process of recovery of glycerine, fats, etc., from waste water.

Glycerol and fatty matters, or betaine, are extracted by evaporating the wash to dryness and extracting the residue with a mixture of absolute alcohol and a solvent, such as acetone or carbon tetrachloride, which is soluble in alcohol. Or, before it is dried, the wash is preferably treated for the removal of succinic, tartaric, citric, lactic, and other organic acids.

Fr. 445895. Watrigant Freres & Co. App. September 16, 1911; Pat. September 17, 1911; Pub. November 21, 1912.

Br. 21060/12. Watrigant Freres & Co. App. September 16, 1912; Acc. September 16, 1913.

Ger. 263354. Watrigant Freres & Co. Pat. September 10, 1912; Pub. August 6, 1913.

*Title:* Process of obtaining glycerine from waste water.

The residues are dried as completely as possible and extracted with various liquids in which the glycerine is insoluble under the conditions of the treatment, after which they are washed with hot amyl alcohol, and from this extract the dissolved glycerine separates on cooling. For instance, acetone may be used in the preliminary washing to dissolve potassium malate, while ethyl acetate is subsequently employed to dissolve the betaine. Ethyl acetate or a cold saturated solution of glycerine in amyl alcohol may be used to extract both potassium malate and betaine.

Fr. 447138. Riviere, L. App. October 18, 1911; Pat. October 19, 1912; Pub. December 23, 1912.

First Addition. Riviere, L. Pat. August 27, 1912.

*Title:* Rational treatment of wine and distillery vinasse.

Potash is recovered from the vinasse by either sodium silicofluoride or an alcoholic solution of sodium perchlorate. The residue is concentrated and treated with alcohol for the recovery of glycerine. The filtered solids from the alcohol treatment, after washing with dilute sodium carbonate, may be used as a fodder. The potash may be recovered from the glycerine instead of from the original vinasses. The fats present in the wine or vinasse are saponified by lime. The calcium soap, after separation from the liquid, is converted into soluble soaps or free fatty acids. The filtrate from the calcium soap is concentrated under reduced pressure, mixed with alcohol and filtered from protein matters. The cakes of the latter are treated in the filter-press with compressed air, carbon dioxide, or other gas, and afterwards dried for fodder. Alcohol is removed from the filtrate by distillation under reduced pressure, the residue is mixed with fine sand or similar material and the glycerol extracted with acetone.

Fr. 453073. Gouthiere, H., & Co., and Ducancel, P. App. March 25, 1912; Pat. March 26, 1913; Pub. May 30, 1913.

*Title:* Process of treatment of distillery vinasses for the extraction of glycerine and food material for cattle.

The glycerine is distilled with steam at reduced pressures from a mixture of concentrated vinasse, spent wash, and pulp. The process is intended particularly for grain fermentations.

U. S. 1344850. } Bassett, H. P. App. July 12, 1919; Pat. June 29, 1920.  
U. S. 1344851. }

*Title:* Process of treating distiller's slop.

Boiling slops with lime converts the carbohydrates into salts of the hydroxyacids of the lactic acid series. Upon acidifying, the latter are decomposed with the formation of aldehydes and acids of the volatile fatty-acid series. Formic and acetic acids may be recovered by distillation. The solution is treated with a mixture of ferrous and ferric sulphate and made alkaline, precipitating basic iron salts of the fatty acids. The mixture is filtered and evaporated until about two-thirds of the potassium salts separate. The decanted liquid contains about 50 per cent glycerine, which is recovered by steam distillation.

U. S. 1357138. Bassett, H. P. App. November 3, 1919; Pat. October 26, 1920.

*Title:* Process of treating distiller's slop.

Distiller's slop is subjected to the action of the higher hydroxide of a metal which is capable of forming higher and lower hydroxides, and capable also of forming an insoluble basic salt with volatile fatty acids. The hydroxide is maintained in the higher state of oxidation by suitable oxidizing treatment, the liquid is acidified, and glycerol is separated from it.

U. S. 1396006. Backhaus and Haner, assignors to U. S. Industrial Alcohol Co. App. October 22, 1917; Pat. November 8, 1921.

*Title:* Method of treating distillery waste.

Distillery slop from the alcohol industry is treated with caustic alkali and the mixture dried to a clinker, which contains sodium salts of oxalic, acetic, formic, and butyric acids. This is heated with dilute sulphuric acid, and lime is added to precipitate calcium oxalate, which is filtered out. A further addition of sulphuric acid is made to the filtrate after its evaporation nearly to dryness and the liberated volatile acids are distilled in vacuo. A temperature of 175-250° C. is suitable for forming the clinker.

U. S. 1396007. Backhaus, A. A., assignor to U. S. Industrial Alcohol Co. App. October 22, 1917; Pat. November 8, 1921.

*Title:* Process of treating distillery waste.

In the process described in U. S. 1396006, carbon dioxide is passed into the filtrate, after precipitating calcium oxalate, in order to precipitate sodium bicarbonate, which is filtered out, incinerated, and heated with lime to regenerate sodium hydroxide.

U. S. 1396008. } Backhaus, A. A., assignor to U. S. Industrial Alcohol Co. App.  
 U. S. 1396009. } October 22, 1917; Pat. November 8, 1921.  
 U. S. 1396010. }

*Title:* Process of producing organic acids.

Distillery slop is concentrated to 25° B., 25 parts are mixed with 8 parts of sodium hydroxide and iron oxide, manganese dioxide, or cerium oxide, 1 part, and the

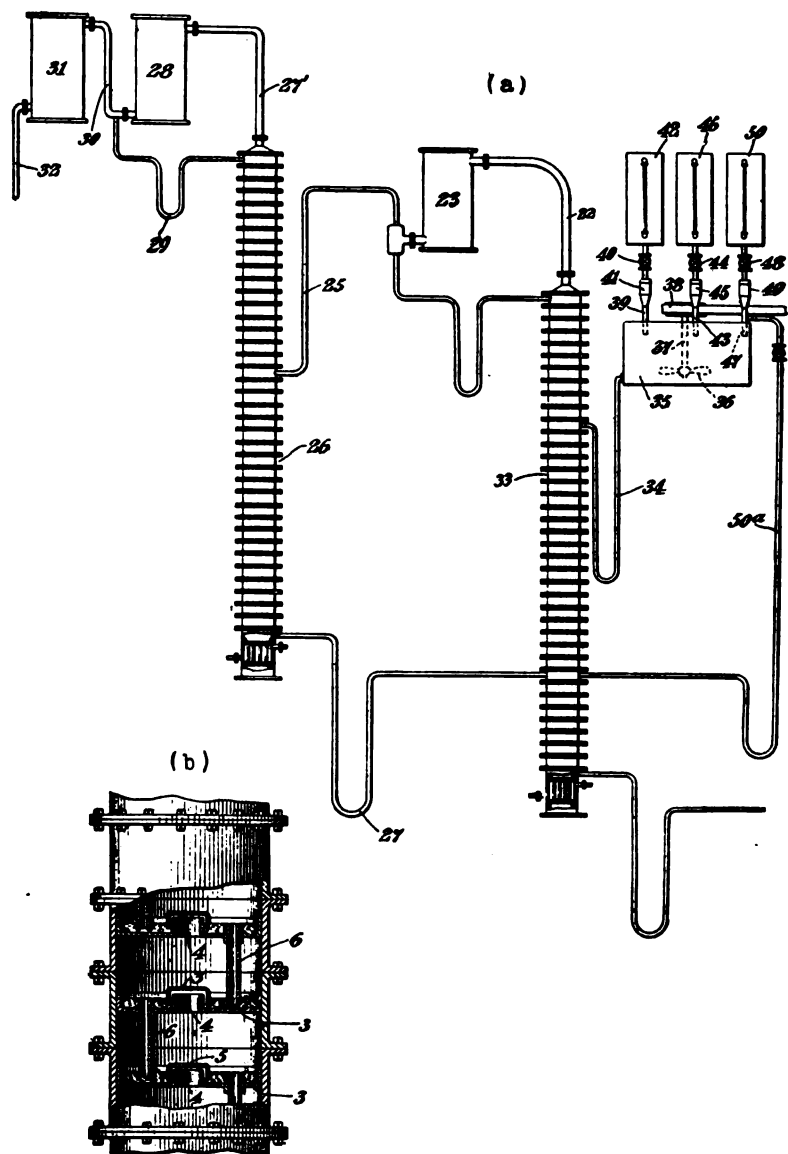


FIG. 45.—U. S. 1400852. (See p. 60.)

mixture is heated for 4-20 hours at 160-250° C. in order to produce sodium salts of organic acids in larger amount, more quickly, or at a lower temperature than without the use of the oxides as catalysts.

U. S. 1396368. Haner, C., assignor to U. S. Industrial Alcohol Co. App. October 22, 1917; Pat. November 8, 1921.

*Title:* Process of treating distillery waste.

Distillery waste is concentrated to a magma and then heated to 175–250° C. for 8–24 hours with sodium hydroxide to form a clinker rich in sodium salts of organic acids. This product is treated with oxalic acid to liberate the volatile organic acids and the latter are distilled in vacuo. The residue is treated with water and lime to precipitate calcium oxalate and the latter is filtered out and decomposed with sulphuric acid to obtain oxalic acid, which is crystallized after separation from calcium sulphate by filtration. The filtrate first obtained after adding lime may be concentrated to regenerate sodium hydroxide.

U. S. 1400852. Backhaus, A. A., assignor to U. S. Industrial Alcohol Co. App. May 23, 1919; Pat. December 20, 1921.

*Title:* Esters from fermented distillery waste.

Acid-fermented distillery waste containing organic acids is passed in countercurrent to gradually increasing concentrations of an alcohol; for example, methyl alcohol, in the presence of a catalyst, such as sulphuric acid, while continually distilling off the ester produced.

U. S. 1426457. Burghart, L. M., assignor to U. S. Industrial Alcohol Co. App. June 24, 1918; Pat. August 22, 1922.

*Title:* Process of recovering volatile organic acids from distillery waste.

A mixture of concentrated distillery slop and sodium hydroxide is dried and heated to form a clinker. This is heated and agitated with dilute sulphuric acid to effect neutralization, and the solution thus formed is filtered, after addition of lime to precipitate calcium oxalate. The filtrate, which contains sodium salts of volatile organic acids, such as formic, acetic, and butyric, is heated in a refluxing column still with sulphuric acid and methyl alcohol or other alcohol to obtain crude esters.

#### (b) FERTILIZERS, FEED, ETC.

Br. 6931/01. Fischel, I. App. April 2, 1901; Acc. May 24, 1901.

*Title:* Improvements in treating waste liquors of sugar manufacture.

A process is described to convert molasses, waste water, etc., into an easily portable form by absorbing in porous substances, such as sawdust, cotton waste, beet slices, etc., and drying.

U. S. 965521. Hoffman, E. A. App. June 24, 1909; Pat. July 26, 1910.

*Title:* Reducing distillery slop to dry feed.

By separating the slop as it is withdrawn from the distillery beer still into thick and thin slops, heating the thin slop to the boiling point, adding sufficient alkaline substance, such as lime, sodium carbonate, sodium hydroxide, potassium hydroxide, ammonia, or barium hydroxide to coagulate it, mixing with the thick slop and drying the residue.

U. S. 1134921. Sinsheimer, S. W. App. May 10, 1913; Pat. April 6, 1915.

*Title:* Concentrated product of nitrogen and potash and process of recovering and solidifying same.

A fertilizer is prepared from the waste liquor remaining after the sugar has been separated from molasses by heating to about 100° C. to precipitate part of the lime and sugar, filtering the hot liquid, and treating the filtrate with hot furnace gases, filtering out the precipitate thus formed, and concentrating and drying in a vacuum at a low temperature.

U. S. 1147767. Laszloffy, A. von. App. January 30, 1911; Pat. July 27, 1915.

*Title:* Manufacture of by-products from distillery slop.

Distillery slop is concentrated to a sirupy consistency and extracted with alcohol to precipitate the albumins, dextrans, gums, etc., which are used for stock food.

U. S. 1147768. Laszloffy, A. von. App. August 25, 1911; Pat. July 27, 1915.

U. S. 1147769. Laszloffy, A. von. App. February 26, 1912; Pat. July 27, 1915.

U. S. 1147770. Laszloffy, A. von. App. October 20, 1913; Pat. July 27, 1915.

*Title:* Manufacture of by-products from distillery slops.

Ether and alcohol are used as solvents for the recovery of acids, fats, and glycerol.

Br. 9270/15. Kaplan and Thompson. App. June 24, 1915; Acc. March 2, 1916.

*Title:* Fertilizer from molasses and vinasse.

Spent liquor is concentrated to 44° B., adding 30–50 per cent ground phosphate, guano, or bone meal, and treating with sufficient sulphuric acid to convert the phosphates to acid phosphate and potassium salts to sulphates.

U. S. 1212484. Herzka, E. App. October 24, 1916; Pat. January 16, 1917.

*Title:* Process of manufacturing fertilizer out of Steffen waste water, etc.

Steffen waste water or similar waste waters obtained in the extraction of sugar from beets are concentrated to 55° Brix, treated with sulphuric acid sufficient to neutralize the lime and other alkalis in the liquor, mixed with calcium superphosphate, sawdust, and nitrogenous animal wastes, and the mixture is dried.

#### (c) DYEING AND MORDANTING MATERIALS.

Br. 20851/02. Schrader, H. App. September 24, 1902; Acc. June 25, 1903.

*Title:* Improved process for obtaining and utilizing the organic acids contained in the residual liquors of molasses.

The process uses waste waters from the calcium, barium, or strontium desugarizing processes, or distiller's slop. The organic acids, such as betaine acids, are left in the residual liquors to use as a mordant in dyeing wool. The residual liquors or waste waters are concentrated to 1.4 specific gravity, then mixed warm with sulphuric acid (92 per cent) to neutrality. Potassium sulphate is separated from solution, and the residual sulphuric acid is separated by precipitation after dilution. The filtrate is decolorized. It finally has a specific gravity of 1.1–1.2, and contains 24 per cent of acid of a molecular weight of 135. This liquor is used in combination with metallic mordants for treating and dyeing wool.

Ger. 141564. Schrader, H. Pat. February 1, 1902; Pub. May 13, 1903.

U. S. 761412. Schrader, H. App. July 1, 1902; Pat. May 31, 1904.

U. S. 735599. Schrader, H. App. March 19, 1903; Pat. August 4, 1903.

Fr. 328160. Schrader, H. App. December 1, 1902; Pat. December 1, 1903; Pub. February 8, 1904.

*Title:* Process of manufacture of organic acids contained in molasses waste water.

In addition to the information given in Br. 20851/02, the use of barium carbonate to neutralize the sulphuric acid is added, and the use of animal and vegetable charcoal to decolorize.

Ger. 167122. Wichardt, O. Pat. April 3, 1904; Pub. December 30, 1905.

*Title:* Process for the manufacture of green to blue dyestuffs containing molybdenum.

Ammonium molybdate reacts on molasses, waste water, or beet juices, when heated. Acid is added and the precipitation of the dyestuff is completed by the addition of alcohol. The intensity of the color is determined by the quantity of sulphuric acid added and varies from light green to dark blue. The dyes are for dyeing wool and silk, and for use as pigments.

#### (d) MISCELLANEOUS PRODUCTS—ALKALIES, PHOSPHATES, ETC.

Fr. 59268. Evrard. Pat. July 17, 1863.

*Title:* Preparation of various products from molasses vinasses and analogous materials.

Vinasses are concentrated to 40° B., potassium nitrate separates out and is leached. The mother liquor is introduced into a cylindrical retort and dry distilled, yielding

wood spirit and nitrogenous products, especially ammonium carbonate. These products are then led into a cylinder containing alkaline char from a previous distillation and are converted to cyanides, potash and soda. If finely divided iron be added to the char before calcination, potassium ferrocyanide is formed.

Ger. 28838. Propfe, H. Pat. March 18, 1884; Pub. August 25, 1884.

*Title:* Process of recovery of tar products and alkalies by distillation of desugared wastes of molasses desugarizing with hard coal tar or tar oils.

Peat is added to lyes, then tar. The mixture is distilled in iron or clay retorts. The gases are driven over by steam, and at the end the residue is in the form of a porous coke. If it is desired to recover the alkalies, lime is added before calcination.

Fr. 396288. Verbieke, F., and Darras-Verbieke, E. App. January 21, 1908; Pat. January 22, 1909; Pub. April 6, 1909.

Fr. Addition No. 10370. Verbieke, F., and Darras-Verbieke, E. App. January 19, 1909; Pat. April 7, 1909; Pub. June 24, 1909.

*Title:* Process of treating vinasses of distilleries.

The vinasses are clarified with iron chloride and aluminum sulphate. Lime is added as a milk to precipitate the clarifying agents, matter in suspension, phosphates, a large part of the nitrogen, various acids, and organic matter. This precipitate is filtered on a press, the press cakes dried and used as fertilizer. The excess of lime is carbonated. The powdered cake from beet vinasses contains about 5 per cent phosphate and 5 per cent nitrogen.

Fr. 485597. Dupont, L. App. July 25, 1916; Pat. October 30, 1917; Pub. January 23, 1918.

*Title:* Process of treating beet and cane molasses, and vinasses therefrom, to obtain ammonia, amines, acids, and other organic compounds.

The initial materials are treated at about 300° C. with caustic alkali to expel ammonia, which is recovered by known means. The residues from this treatment afford solid salts or organic acids, especially oxalic and acetic, which are separated by difference of solubility. Certain volatile organic compounds are obtained with the ammonia, such as amines, phenolic and alcoholic bodies.

U. S. 1342737. Bradford and Broadhead. App. September 16, 1918; Pat. June 8, 1920.

*Title:* Method of recovering by-products from waste liquors.

Steffen waste water is concentrated to about 30° B. and then subjected to the action of an electric current of sufficient intensity to produce an arc in the liquor. This effects evaporation with electrolytic dissociation and then complete combustion. The gaseous products of evaporation and combustion are collected and cooled to recover methylamine, cyanogen, methyl chloride, and the residue is leached to obtain the potassium chloride.

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Fr. 442923. Gouthiere, H., & Co., and Ducancel, P. Group 2 (a).

Fr. 353970. Guerrero, W. de S. Group 2 (b).

Br. 17347/87. Meyer, E. Group 2 (a).

Ger. 43345. Meyer, E. Group 2 (a).

U. S. 396705. Meyer, E. Group 2 (a).

Fr. 385139. Riviere, L. Group 6.

Ger. 215531. Societe Anonyme de Recuperation de Produits Chimiques "Procede Effront." Group 2 (a).

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Specification,  
No. 66.

DEPARTMENT OF COMMERCE.

U. S. BUREAU OF STANDARDS.

George K. Burgess, Director.

CIRCULAR OF THE BUREAU OF STANDARDS, NO. 146.

[Issued September 25, 1923.]

UNITED STATES GOVERNMENT SPECIFICATION FOR  
WATER-RESISTING RED ENAMEL.

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION NO. 66.

This specification was officially adopted by the Federal Specifications Board on September 1, 1923, for the use of the Departments and Independent Establishments of the Government in the purchase of water-resisting red enamel.

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1. GENERAL.

The material desired under this specification is an extremely durable, highest quality red enamel, suitable primarily for outside use. It should be made by grinding pure high color strength toluidine red toner (metanitro-paratoluidine-azo-betanaphthol), free from any base or substratum, with the very best water-resisting long oil spar varnish. The color and hiding power when specified shall be equal to those of a sample mutually agreed upon by buyer and seller. It must meet the following requirements:

WEIGHT PER GALLON.—Not less than  $7\frac{1}{2}$  pounds.

PIGMENT.—Not less than 6 per cent by weight; pigment to be composed entirely of pure high color strength toluidine red toner, free from any other organic coloring matter, base, or substratum.

**COARSE PARTICLES AND "SKINS"** (total residue retained on No. 325 sieve).—Not more than 0.5 per cent.

**NONVOLATILE MATTER**.—Not less than 60 per cent by weight.

**SET TO TOUCH**.—In not more than 18 hours.

**DRY HARD AND TOUGH**.—In not more than 48 hours.

**WORKING PROPERTIES**.—Enamel must have good brushing, flowing, covering, and leveling properties and must not cake in the container.

**WATER RESISTANCE**.—Dried film must withstand cold water for 18 hours and boiling water for 15 minutes without whitening, dulling, or change in color.

**TOUGHNESS**.—Enamel must pass a 50 per cent Kauri reduction test at 24° C. (75° F.).

*Deliveries will, in general, be sampled and tested by the following methods, but the purchaser reserves the right to use any additional available information to ascertain whether the material meets the specification.*

## 2. SAMPLING.

It is mutually agreed by buyer and seller that a single package out of each lot of not more than 1,000 packages be taken as representative of the whole. Whenever possible, an original unopened container shall be sent to the laboratory, and when for any reason this is not done the inspector shall thoroughly mix the contents of the container sampled, transfer not less than 1 quart to a clean, dry glass bottle or tin can, which must be nearly filled with the sample, securely stoppered with a new, clean cork or well-fitting cover or cap, sealed and distinctly labeled by the inspector. The inspector should take a duplicate from the container sampled to be held for check in case of dispute, and, when requested, should take a sample for the seller.

## 3. LABORATORY EXAMINATION.

The tin panels used in the following tests shall all be cut from bright tin plate weighing not more than 25 nor less than 19 g per square decimeter (0.51 to 0.39 pound per square foot). (Commercial No. 31 gauge bright tin plate should weigh about 0.44 pound per square foot. It is important that the tin plate used shall be within the limits set.) The panels shall be about 7.5 by 13 cm (3 by 5 inches) and must be thoroughly cleaned with benzol immediately before using.

(a) **CAKING IN CONTAINER AND WORKING PROPERTIES**.—When an original package is received in the laboratory, it shall be

weighed, opened, and stirred with a stiff spatula or paddle. The enamel must be no more difficult to break up than a normal good grade of enamel paint. The enamel shall finally be thoroughly mixed, removed from the container, and the container wiped clean and weighed. This weight subtracted from the weight of the original package gives the net weight of the contents. Apply some of the thoroughly mixed enamel, both by brushing and flowing, to clean glass plates. It should work easily under the brush. Dry both plates in a nearly vertical position. They should both dry without streaking, separating, or showing brush marks. A portion of thoroughly mixed enamel shall be placed in a clean container and the portions for the remaining tests promptly weighed out.

(b) COLOR AND HIDING POWER.—Place some of the enamel on a clean, clear glass plate. Place some of the standard agreed upon beside the sample on the plate, turn the glass over, and compare the colors by transmitted and reflected light.

(c) WEIGHT PER GALLON.—Weigh a clean, dry, 100 cc graduated flask. Fill to the mark with the thoroughly mixed enamel and weigh again. The increase in weight expressed in grams, divided by 100, gives the specific gravity, which, multiplied by 8.33, gives the weight in pounds per gallon.

(d) COARSE PARTICLES AND SKINS.—Dry in an oven at 105 to 110° C. a No. 325 sieve, cool, and weigh accurately. Weigh accurately about 50 g of the enamel, add 100 cc of kerosene, mix thoroughly, and wash with kerosene through the sieve, breaking up all lumps, but not grinding. After washing with kerosene until all but the particles too coarse to pass the sieve have been washed through wash all kerosene from the sieve with ether or petroleum ether, heat the sieve for one hour at 105 to 110° C., cool, and weigh.

(e) PIGMENT.—*Qualitative examination.*—Pour about 1 g of the thoroughly stirred enamel, previously strained through a No. 200 sieve in a 50 cc beaker. Add about 40 cc of chloroform (U. S. P.) and warm on the steam bath, stirring with a glass rod. A clear orange-red solution should result in a few minutes. Take another portion of the enamel and spread it with a spatula on a smooth, white surface, such as a piece of milk glass. Touch a few drops of alcoholic sodium hydroxide solution to the center of the film and rub well with a glass spatula. There should be no change in color.<sup>1</sup>

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<sup>1</sup> The presence of para nitraniline red is indicated by a violet color.

*Quantitative determination.*—Weigh 1 g ( $\pm 10$  mg) of the enamel and 6 g ( $\pm 10$  mg) of pure zinc oxide, place on a large glass plate, add 2 cc of linseed oil and rub up with a flat-bottomed glass pestle or muller, grinding with a circular motion 50 times. Gather up with a sharp-edge spatula and grind out twice more in like manner, giving the pestle a uniform pressure. Next weigh to  $\pm 1$  mg an amount of pure high color strength toluidine red toner equal to 6 per cent of the weight of enamel taken, add 4 drops of linseed oil and rub up with the glass pestle. Then add 6 g of pure zinc oxide and 2 cc of linseed oil and treat in exactly the same manner as described above. Transfer portions of each paste to a clean microscope slide quite close together, and then draw a palette knife across both samples, so as to make them meet in a line. Compare the tints as shown on both sides of the glass. The color of the sample tested shall be not less than that of the selected standard, and the tone shall be not materially different from it.

(f) NONVOLATILE MATTER.—Place a portion of the sample in a stoppered bottle or weighing pipette. Weigh container and sample. Transfer about 1.5 g of the sample to a weighed flat-bottomed metal dish about 8 cm in diameter (a friction-top can plug). Weigh container again and by difference calculate the exact weight of the portion of sample transferred to the weighed dish. Heat dish and contents in an oven maintained at 105 to 110° C. (221 to 230° F.) for three hours. Cool and weigh. From the weight of the residue left in the dish and weight of the sample taken calculate the percentage of nonvolatile residue.

(g) DRYING TIME.—Pour the enamel on one of the tin panels described above. Place the panel in a nearly vertical position in a well-ventilated room, but not in the direct rays of the sun. The atmosphere of this room must be free from products of combustion or laboratory fumes. The temperature of the room should be from 21 to 32° C. (70 to 90° F.). The film is tested at points not less than 2.5 cm (1 inch) from the edges of the film by touching lightly with the finger. The enamel is considered to have set to touch when gentle pressure of the finger shows a tacky condition, but none of the enamel adheres to the finger. The enamel is considered to have dried hard when the pressure that can be exerted between the thumb and finger does not move the film or leave a mark which remains noticeable after the spot is lightly polished. If rapid, light rubbing breaks the surface, the sample is considered not to have satisfactorily dried hard. In case the test shows time of setting to touch or drying hard more than 18 and 48 hours,

respectively, two additional tests shall be run on different days, and if the enamel does not meet the above drying and hardening requirements on both of these additional tests it shall be considered unsatisfactory. In cases where different laboratories fail to agree on the drying test, due to different atmospheric conditions, and umpire tests are necessary, such tests shall be made in a well-ventilated room maintained at a temperature of 70° F. and relative humidity of 65 per cent saturation.

(h) **WATER RESISTANCE.**—Pour the enamel on two of the tin panels described above and allow to dry under the conditions described in paragraph (g) for 48 hours. Place one of these panels in a beaker containing about 2.5 inches of distilled water at room temperature (immersing the end of the panel which was uppermost during the drying period) and leave in water for 18 hours. The enamel shall show no whitening and no more than very slight dulling either when observed immediately after removing from the water or after drying for 2 hours. Place the other panel in a beaker containing about 2.5 inches of boiling distilled water (immersing the end of the panel which was uppermost during the drying period) and allow to remain in the boiling water for 15 minutes. The enamel shall show no whitening, no more than a very slight dulling, and no material change in color, either when observed immediately after removing from the water or after drying for 2 hours.

(i) **TOUGHNESS.**—The toughness of the enamel is determined by the Kauri reduction test, as follows: By proportionately reducing its toughness by the addition of a standard solution of "run-Kauri" gum in pure spirits of turpentine.

(1) *Preparation of the "run Kauri."*—Arrange a distillation flask, water-cooled condenser, and a tared receiver on a balance. Place in the flask about one-third of its volumetric capacity of clear, bright hard pieces of Kauri gum broken to pea size. Carefully melt and distil until 25 per cent, by weight, of the gum taken is collected in the tared receiver. (At the end of the distillation the thermometer in the distillation flask with the bulb at the level of the discharging point of the flask should register about 316° C. (600° F.).) Pour the residue into a clean pan, and when cold break up into small pieces.

(2) *Preparation of standard "run-Kauri" solution.*—Place a quantity of the small broken pieces of run-Kauri, together with twice its weight of freshly redistilled spirits of turpentine, using only that portion distilling over between 153 and 170° C. (308 and 338° F.) in a carefully tared beaker. Dissolve by heating

to a temperature of about 149° C. (300° F.) and bring back to correct weight when cold by the addition of the amount of redistilled spirits of turpentine necessary to replace the loss by evaporation during the dissolving of the gum.

(3) *Reduction of the enamel.*—Having carefully determined the nonvolatile content of the enamel according to the method under paragraph (f) of this specification, take 100 g of the enamel and add to it an amount of the standard run-Kauri solution equivalent to 50 per cent, by weight, of the nonvolatile matter in the enamel. Mix the enamel and the solution thoroughly.

(4) *Application of the enamel.*—Flow a coat of the enamel thus reduced on one of the tin panels described above and let stand in a nearly vertical position at room temperature for one hour. Next place the panel in a horizontal position in a properly ventilated oven and bake for five hours at 95 to 100° C. Remove the panel from the oven and allow to cool at room temperature, preferably 24° C. (75° F.) for one hour.

(5) *Bending the panel.*—Place the panel with the enameled side uppermost over a 3-mm ( $\frac{1}{8}$  inch) rod, held firmly by suitable supports, at a point equally distant from the top and bottom edges of the panel and bend the panel double rapidly. The enamel must show no cracking whatsoever at the point of bending. For accurate results the bending of the panel should always be done at 24° C. (75° F.), for a lowering of the temperature will lower the percentage of reduction that the enamel will stand without cracking, while an increase in the temperature increases the percentage of reduction that the enamel will stand.

#### 4. BASIS OF PURCHASE.

Enamel shall be purchased by volume, the unit being a gallon of 231 cubic inches at 15.5° C. (60° F.). The volume may be determined by measure or, in case of large deliveries, it may be easier to determine the net weight and specific gravity at 15.5/15.5° C. (60/60° F.) of the delivery. The weight per gallon in pounds can then be determined by multiplying the specific gravity by 8.33. The net weight in pounds divided by the weight per gallon gives the number of gallons.

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U. S. Gov't  
Standard  
Specification,  
No. 67.

DEPARTMENT OF COMMERCE.

U. S. BUREAU OF STANDARDS.

George K. Burgess, Director.

CIRCULAR OF THE BUREAU OF STANDARDS NO. 147.

(Issued September 19, 1923.)

UNITED STATES GOVERNMENT SPECIFICATION FOR  
GLOSS INTERIOR LITHOPONE PAINT, WHITE AND  
LIGHT TINTS.

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION NO. 67.

This specification was officially adopted by the Federal Specifications Board on September 1, 1923, for the use of the Departments and Independent Establishments of the Government in the purchase of gloss interior lithopone paint, white and light tints.

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1. GENERAL.

This specification covers ready-mixed lithopone paints, frequently known as gloss mill white, in white and a variety of light tints. Paints under this specification are not intended for outside exposure. They shall dry to gloss opaque coats that will adhere well to wood, metal, and plaster, stand washing with soap and water, and show no material change in color on exposure to light or material yellowing when kept in the dark.

The paint shall be purchased by volume (231 cubic inches to the gallon).

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(a) PIGMENT.—The pigment shall consist of :

	Maximum.	Minimum.
	Per cent.	Per cent.
Lithopone <sup>1</sup> .....		65
Zinc oxide.....		20
Tinting and extending pigments.....	5.0	
Material soluble in water.....	0.8	

<sup>1</sup> The lithopone used must contain not less than 26 per cent of zinc sulphide and must not darken on exposure.

In no case shall the sum of zinc oxide and lithopone be less than 95 per cent.

(b) LIQUID.—The liquid portion of the paint shall consist of treated drying oils or varnish, or a mixture thereof, and turpentine or volatile mineral spirits, or a mixture thereof, in such proportions as to insure not less than 60 per cent of nonvolatile vehicle. The nonvolatile vehicle shall dry to a tough and elastic film.

(c) PAINT.—The paint shall be well ground, shall not settle badly, cake, or thicken in the container, shall be readily broken up with a paddle to a smooth, uniform paint of brushing consistency, and shall dry within 24 hours to a varnish gloss finish without streaking, running, or sagging, and free from laps and brush marks. The color and hiding power when specified shall be equal to those of a sample mutually agreed upon by buyer and seller. After drying for not less than five days marks made on the painted surface with a soft lead pencil (No. 2 Mogul) shall be easily removed by washing with soap and warm water without appreciably marring the paint surface. The weight per gallon shall be not less than 12½ pounds. The paint shall consist of:

	Maximum.	Minimum.
	Per cent.	Per cent.
Pigment.....	60	50
Liquid (containing at least 60 per cent nonvolatile matter).....	50	40
Water.....	1	
Coarse particles and "skins" (total residue retained on No. 325 screen based on pigment).....	0.5	

*Deliveries will, in general, be sampled and tested by the following methods, but the purchaser reserves the right to use any additional available information to ascertain whether the material meets the specification.*

## 2. SAMPLING.

It is mutually agreed by buyer and seller that a single package out of each lot of not more than 1,000 packages shall be taken as representative of the whole. Whenever possible, an original

unopened container shall be sent to the laboratory, and when this is for any reason not done the inspector shall determine by thorough testing with a paddle or spatula whether the material meets the requirement regarding caking in the container. He shall then thoroughly mix the contents of the container and draw a sample of not less than 5 pounds. This sample shall be placed in a clean, dry metal or glass container, which it must nearly fill. The container shall be closed with a tight cover, sealed, marked, and sent to the laboratory for test with the inspector's report on caking.

When requested, a duplicate sample may be taken from the same package and delivered to the seller, and the inspector may take a third sample to hold for test in case of dispute.

### 3. LABORATORY EXAMINATION.

(a) **CAKING IN CONTAINER.**—When an original package is received in the laboratory, it shall be weighed, opened, and stirred with a stiff spatula or paddle. The paint must be no more difficult to mix to a uniform consistency than a good grade of gloss mill white. The paint shall finally be thoroughly mixed, removed from the container, and the container wiped clean and weighed. This weight subtracted from the weight of the original package gives the net weight of the contents. A portion of the thoroughly mixed paint shall be placed in a clean container and portions for the remaining tests promptly weighed out.

(b) **COLOR.**—Place some of the paint on a clean, clear glass plate. Place some of the standard agreed upon beside the sample on the plate, turn the glass over, and compare the colors.

(c) **WEIGHT PER GALLON.**—Weigh a clean, dry, 100 cc graduated flask. Fill to the mark with the thoroughly mixed paint and weigh again. The increase in weight expressed in grams, divided by 100, gives the specific gravity, which, multiplied by 8.33, gives the weight in pounds per gallon.

(d) **BRUSHING PROPERTIES, TIME OF DRYING, AND RESISTANCE TO WASHING.**—Brush the well-mixed paint on a suitable panel, which may be ground glass, steel, or well-filled wood. Note whether the paint works satisfactorily under the brush. Place the panel in a vertical position in a well-ventilated room and let it stand for 24 hours. The paint should be dry and free from streaks. Let the panel stand for five days, then make marks on it with a soft lead pencil (No. 2 Mogul) and wash these marks off with warm (75° C.) distilled water and white floating soap, using

a sponge or soft rag. The marks must be removed by this treatment without appreciably marring the paint film.

Flow a portion of the paint on a clean glass plate. Let dry in a nearly vertical position at room temperature (65 to 100° F.). The film shall show no streaking or separation within a distance of 4 inches from the top.

(e) **FASTNESS TO LIGHT.**—Apply a sufficient number of coats of the paint to a ground-glass plate to completely hide the surface, cover half of this painted surface with opaque black paper, and expose indoors in a well-lighted room for five days. Remove the black paper and examine the surface. The exposed portion should be no darker than the portion protected by the black paper.

(f) **YELLOWING.**—Apply a sufficient number of coats of the paint to two ground-glass plates to completely hide the surface; after applying the last coat let dry in a well-lighted room for five days. Place one of the plates in a dark room or cabinet<sup>1</sup> with a warm, very humid atmosphere, for 96 hours. Remove from cabinet and compare with the plate that has been kept in a light room. The plate kept in the dark shall be only slightly yellower than the plate kept in the light. There shall be no greater difference in color of the two plates than there will be with similar plates coated with the best grade of paint of this general nature.

(g) **WATER.**—Mix 100 g of the paint in a 300 cc flask with 75 cc of toluol. Connect with a condenser and distil until about 50 cc of distillate has been collected in a graduate. The temperature in the flask should be then about 105 to 110° C. The number of cubic centimeters of water collecting under the toluol in the receiver is the percentage of water in the paint.

(h) **VOLATILE THINNER.**—Weigh accurately from 3 to 5 g of the paint into a tared flat-bottomed dish about 5 cm in diameter, spreading the paint over the bottom. Heat at 105 to 110° C. for one hour, cool, and weigh. Calculate the loss in weight as percentage of water and volatile thinner, subtract from this the percentage of water (3, g), and report the remainder as volatile thinner.

(i) **PERCENTAGE OF PIGMENT.**—Weigh accurately about 15 g of the paint into a weighed centrifuge tube. Add 20 to 30 cc of "extraction mixture" (see Reagents), mix thoroughly with a

<sup>1</sup> A convenient cabinet for this test is described in Circular No. 152, Educational Bureau, Scientific Section, Paint Manufacturers' Association of the United States.

glass rod, wash the rod with more of the extraction mixture, and add sufficient of the reagent to make a total of 60 cc in the tube. Place the tube in the container of a centrifuge, surround with water, and counterbalance the container of the opposite arm with a similar tube or a tube with water. Whirl at a moderate speed until well settled. Decant the clear supernatant liquid. Repeat the extraction twice with 40 cc of extraction mixture and once with 40 cc of ether. After drawing off the ether set the tube in a beaker of water at about 80° C. or on top of a warm oven for 10 minutes, then in an oven at 110 to 115° C. for two hours. Cool, weigh, and calculate the percentage of pigment. Grind the pigment to a fine powder, pass through a No. 80 sieve to remove any skins, and preserve in a stoppered bottle. Preserve the extracted vehicle for 3 (*k*).

(*j*) PERCENTAGE OF NONVOLATILE VEHICLE.—Add together the percentages of water (3, *g*), of volatile thinner (3, *h*), and of pigment (3, *i*), and subtract the sum from 100. The remainder is the percentage of nonvolatile vehicle.

(*k*) NATURE OF NONVOLATILE VEHICLE.—Evaporate the extracted vehicle and extraction mixture from 3 (*i*) to about 5 cc. Thoroughly clean with benzol. a piece of bright sheet iron, tin plate, or terneplate. Spread a portion of the concentrated extracted vehicle on the sheet of metal, allow to dry for 30 minutes at room temperature in a vertical position, bake for three hours at 100 to 110° C. (212 to 221° F.), remove from the oven, and keep at room temperature for three days. Place the panel with the coated side uppermost over a 3 mm ( $\frac{1}{8}$ -inch) rod, held firmly by suitable supports, at a point equally distant from the top and bottom edges of the panel and bend double rapidly. The dried vehicle must show no cracking whatever at the point of bending. Test the film with a knife blade at a place not less than 2.5 cm (1 inch) from the edge. The film should be tough and elastic. If it powders, or if particles fly under the test, it will be considered brittle, which will be cause for rejection. The film must also stand light, vigorous rubbing with the finger without powdering or disintegrating.

(*l*) COARSE PARTICLES AND SKINS.—Dry in an oven at 105 to 110° C. a No. 325 sieve, cool, and weigh accurately. Weigh an amount of paint containing 10 g of pigment (see 3, *i*), add 50 cc of kerosene, mix thoroughly, and wash with kerosene through the sieve, breaking up all lumps, but not grinding. After washing

with kerosene until all but the particles too coarse to pass the sieve have been washed through wash all kerosene from the sieve with ether or petroleum ether, heat the sieve for one hour at 105 to 110° C., cool, and weigh.

#### 4. ANALYSIS OF PIGMENT.

Use the pigment extracted in 3 (i).

(a) **QUALITATIVE ANALYSIS.**—Make qualitative analysis, following ordinary methods.

(b) **MATTER SOLUBLE IN WATER.**—Transfer 2.5 g of the pigment to a graduated 250 cc flask, add 100 cc of water, boil for five minutes, cool, fill to mark with water, mix, and allow to settle. Pour the supernatant liquid through a dry filter paper and discard the first 20 cc. Then evaporate 100 cc of the clear filtrate to dryness in a weighed dish, heat for one hour at 105 to 110° C., cool, and weigh.

(c) **BARIUM SULPHATE AND SILICEOUS MATERIAL.**—Transfer 1 g of pigment to a porcelain casserole or dish, moisten with a few drops of alcohol, add 40 cc of hydrochloric acid (1.1 specific gravity), cover, and boil to expel hydrogen sulphide. Remove the cover and evaporate to dryness on the steam bath, moisten with hydrochloric acid, dilute with water, filter through paper, and wash with dilute hydrochloric acid and then with hot water until the washings are free from zinc and chlorine. Ignite and weigh the residue, which will be barium sulphate and siliceous material.

Mix the ignited residue with about 10 times its weight of anhydrous sodium carbonate (grind the mixture in an agate mortar, if necessary), fuse the mixture in a covered platinum crucible, heating about one hour. Let cool, place the crucible and cover in a 250 cc beaker, add about 100 cc of water, and heat until the melt is disintegrated. Filter on paper (leaving the crucible and cover in the beaker) and wash the beaker and filter thoroughly with hot water to remove soluble sulphates. Place the beaker containing the crucible and cover under the funnel, pierce the filter with glass rod, and wash the carbonate residue into the beaker by means of a jet of hot water. Wash the paper with hot, dilute hydrochloric acid (1:1) and then with hot water. If the carbonate residue is not completely dissolved, add sufficient dilute hydrochloric acid to effect solution and remove the crucible and cover, washing them with a jet of water. Heat the solution to boiling and add 10 to 15 cc of dilute sulphuric acid and continue the boiling for 10 or 15 minutes longer. Let the precipitate

settle, filter on a weighed Gooch crucible, wash with hot water, ignite, cool, and weigh as  $\text{BaSO}_4$ . Subtract from the result of the previous determination to obtain the siliceous material.

(d) **TOTAL ZINC CALCULATED AS ZINC OXIDE.**—With material containing no interfering elements (iron, for example) weigh accurately about 1 g of pigment, transfer to a 400 cc beaker, moisten with alcohol, add 30 cc of hydrochloric acid (1:2), boil for two to three minutes, add 200 cc of water and a small piece of litmus paper; add strong ammonia until slightly alkaline, render just acid with hydrochloric acid, then add 3 cc of strong hydrochloric acid, heat nearly to boiling, and titrate with standard ferrocyanide as in standardizing that solution (see Reagents). Calculate total zinc as zinc oxide.

When iron or other interfering elements are present (see 4, a), take the filtrate containing the zinc from 4 (c), add a slight excess of bromine water and 2 g of ammonium chloride, heat to nearly boiling, add an excess of ammonia, heat for about two minutes, filter, dissolve the precipitate in hydrochloric acid, add 2 g of ammonium chloride, and reprecipitate with ammonia as above. Filter, wash the precipitate with hot 2 per cent ammonium-chloride solution, unite the two filtrates, and determine zinc as above.

(e) **ZINC OXIDE.**—Weigh accurately 2.5 g of pigment, transfer to a 250 cc graduated flask, moisten with a few drops of alcohol, add about 200 cc of 1 to 3 per cent acetic acid, shake vigorously, and let stand for 30 minutes, shaking once every five minutes. Fill to the mark with 1 to 3 per cent acetic acid, mix, filter through a dry paper, discard the first 25 cc, and determine zinc in 100 cc of the filtrate (corresponding to 1 g) as in 4 (d). Calculate the percentage of zinc oxide.

(f) **CALCULATIONS.**—Subtract the percentage of zinc oxide (4, e) from the percentage of total zinc as zinc oxide (4, d) and multiply the remainder by 1.2 to convert to percentage of zinc sulphide. In case the percentage of barium sulphate (4, c) is not more than 2.86 times as great as the percentage of zinc sulphide, add the two together and call the sum the percentage of lithopone. If the percentage of barium sulphate is greater than this amount, take 2.86 times the percentage of zinc sulphide as the percentage of barium sulphate to be included in the percentage of lithopone and include the remainder in the percentage of tinting and extending pigments. Subtract the sum of the percentages of zinc oxide

(4, e), lithopone, and matter soluble in water (4, b) from 100. Call the remainder percentage of tinting and extending pigments.

#### 5. REAGENTS.

(a) **EXTRACTION MIXTURE.**—

10 volumes ether (ethyl ether).

6 volumes benzol.

4 volumes methyl alcohol.

1 volume acetone.

(b) **ONE TO THREE PER CENT ACETIC ACID.**—Dilute 20 cc of glacial acetic acid to 1,000 cc with distilled water.

(c) **URANYL INDICATOR FOR ZINC TITRATION.**—A 5 per cent solution of uranyl nitrate in water or a 5 per cent solution of uranyl acetate in water made slightly acid with acetic acid.

(d) **STANDARD POTASSIUM FERROCYANIDE.**—Dissolve 22 g of the pure salt in water and dilute to 1,000 cc. To standardize, transfer about 0.2 g (accurately weighed) of pure metallic zinc or freshly ignited pure zinc oxide to a 400 cc beaker. Dissolve in 10 cc of hydrochloric acid and 20 cc of water. Drop in a small piece of litmus paper, add ammonium hydroxide until slightly alkaline, then add hydrochloric acid until just acid, and then 3 cc of strong hydrochloric acid. Dilute to about 250 cc with hot water and heat nearly to boiling. Run in the ferrocyanide solution slowly from a burette, with constant stirring until a drop tested on a white porcelain plate with a drop of the uranyl indicator shows a brown tinge after standing one minute. A blank should be run with the same amounts of reagents and water as in the standardization. The amount of ferrocyanide solution required for the blank should be subtracted from the amount used in standardization and in titration of the sample. The standardization must be made under the same conditions of temperature, volume, and acidity as obtain when the sample is titrated.

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U. S. Gov't  
Standard  
Specification.  
No. 37.

DEPARTMENT OF COMMERCE.

U. S. BUREAU OF STANDARDS.

" George K. Burgess, Director.

CIRCULAR OF THE BUREAU OF STANDARDS, NO. 148.

[October 10, 1923.]

UNITED STATES GOVERNMENT SPECIFICATION FOR  
LEATHER BELTING.

FEDERAL SPECIFICATIONS BOARD.

STANDARD SPECIFICATION NO. 37.

This Specification was officially adopted by the Federal Specifications Board on July 3, 1922, for the use of the Departments and Independent Establishments of the Government in the purchase of leather belting.

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I. MATERIAL COVERED.

This specification is for use as the basis of purchase for miscellaneous sizes, single and double ply, of first quality vegetable-tanned (so-called oak tanned) leather belting for general use; also waterproof dressed and waterproof leather belting.

II. STANDARD SPECIFICATION.

1. QUALITY OF THE LEATHER.

(a) HIDES.—All belting leather shall be made from green salted hides and be free from brands, soft or spongy spots, and open

grub holes, excepting that when made into belting 30 per cent of the strips in any belt or roll of belting may contain a maximum of three open grub holes in each of such strips.

(b) TANNING.—The hides shall be tanned with oak bark or a combination of vegetable tanning materials.

(c) CURRYING.—*Stuffing*.—Animal oils and greases shall be used for stuffing the leather, or a mixture of these and mineral oils in such proportion as will provide maximum strength and pliability.

*Adulteration*.—The use of Epsom salts, glucose, barium chloride, or other materials for weighting the leather is prohibited. The presence of a greater amount of stuffing content than hereinafter specified shall be considered as adulteration.

(d) MANUFACTURE.—*Stretching*.—All leather after stuffing shall be thoroughly stretched while still damp, and left under tension until dry. All belt pieces shall have the stretcher marks cut off.

*Finish*.—The grain, or hair side, shall be finished smooth and the leather shall be thoroughly fleshed.

*Cutting*.—All strips shall be cut from the center portion of the hide at such distance from the backbone as to include only firm stock, and exclude second-quality leather, and at such distance from the root of the tail as will exclude all shoulder stock, provided that the length of the strips shall be as hereinafter specified.

## 2. CONSTRUCTION OF THE BELTING.

(a) STRIPS.—*Length*.—No sectional strip shall be more than 54 inches in length, including the lap. The minimum length of any strip shall be 36 inches, including the lap, excepting that in double belts  $\frac{1}{8}$  of the total number of pieces may be between 20 inches and 36 inches, provided that these short pieces do not occur consecutively. The minimum length shall not apply to the end pieces of rolls or cut lengths.

*Joining*.—In single belting the strips shall be joined shoulder end to shoulder end, and butt end to butt end. In double belting the strips shall be joined shoulder end to butt end.

*Selection*.—In all single belts 8 inches and over in width backbone center strips shall be used. The backbone mark must appear running lengthwise approximately in the center of each strip. In all double belts from 8-inch up to 10-inch width, backbone center strips shall be used in one ply and the backbone mark shall appear running lengthwise approximately in the center of each strip. The other ply shall be cut from the location pre-

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*Specification for Leather Belting.*

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scribed for first-quality stock. In all double belts 10 inches and over in width, both plies shall be made from backbone center strips and the backbone mark shall appear running lengthwise approximately in the center of each strip. The same quality of leather shall be used in both plies of all double belting.

(b) LAPS.—*Length.*—The length of laps shall be within the following limits:

TABLE 1.—Length of Laps (in Inches).

Ply.	Thickness.	Length of laps.	
		Belts under 6 inches in width.	Belts 6 inches and over in width.
Single.....	Under 10/64.....	2½ to 6....	3 to 8.
	10/64 and over.....	3 to 8....	3½ to 10.
Double.....	Up to 17/64.....	2½ to 3½..	3 to 4.
	17/64 and over.....	3 to 4.....	3 to 5.

*Location.*—The minimum distance between any two laps in the separate plies of double belting shall be 8 inches.

*Point of lap.*—The points of all laps shall be at right angles to the edge of the belt.

*Direction.*—All laps shall run in the same direction.

(c) CEMENTING.—The laps of both single and double belts and the plies of double belts shall be thoroughly cemented together. When pulled apart the cemented surface shall not appear glazed or shiny.

(d) WIDTH.—*Standard widths.*—The standard widths of belt shall be from ¼ inch to 72 inches, increasing by ¼ inch up to 3 inches, ½ inch up to 6 inches, 1 inch up to 10 inches, and 2 inches above 10 inches.

The maximum variation from the nominal width shall be in accordance with the following:

TABLE 2.—Tolerance from Nominal Width.

Width of belting (in inches).	Tolerance.
Under 2.....	Not less than nominal.
2 to 24, inclusive.....	1 per cent.
Above 24.....	One-half of 1 per cent.

(e) **THICKNESS.**—The thicknesses for the different grades of belting shall be in accordance with the following table:

TABLE 3.—Thicknesses and Grades.

Grade.	Average thicknesses (in inches).	
	Single ply.	Double ply.
Light.....	8/64 up to 10/64.....	15/64 to 17/64.
Medium.....	10/64 up to 12/64.....	19/64 to 21/64.
Heavy.....	12/64 up to 14/64.....	23/64 to 25/64.

The average thickness shall be determined by measuring the thickness of 20 plies of the belt when rolled and dividing this value by the number of plies measured.

*Uniformity.*—No point in either single or double belting shall be more than  $2/64$  inch thicker nor more than  $2/64$  inch thinner than the average thickness.

*Leveling and filling.*—The excessive use of shims and filler strips and excessive splitting or leveling is prohibited.

(f) **MARKING.**—All belting shall be stamped on grain side with the maker's name and brand and a stamp indicating the direction in which the belting is to run. Each stamp shall be repeated every 10 feet throughout the entire length of the belting.

(g) **WATERPROOF BELTING.**—*Waterproof dressed belting.*—This type of belting shall conform to all the requirements of this specification. In addition, it shall be treated with a waterproof dressing.

24. *Waterproof belting.*—This type of belting shall conform to all the requirements of this specification. In addition, it shall be treated with a waterproof dressing. The laps and plies shall be cemented with a waterproof cement.

### III. TECHNICAL TESTS.

#### 1. PHYSICAL TESTS.

(a) **TENSILE STRENGTH.**—*Leather.*—All leather shall have a minimum tensile strength of 3,000 pounds per square inch of cross section, and an average tensile strength for single belts of 3,750 pounds per square inch and for double belts of 3,500 pounds per square inch. The average shall be determined with five test specimens cut continuously lengthwise of the sample, omitting the lap. Test specimens of the shape and size shown in Figure 1 shall be cut with a metal die. The edges of the test specimen

shall be cut perpendicularly. The minimum thickness inside the gauge marks shall be used in determining the area of the cross section of the test specimen.

*Laps and plies.*—The laps of both single and double belting shall not open and the plies of double belting shall not separate when subjected to a tensile stress of 2,500 pounds per square inch. The opening of the laps shall be determined by testing two specimens cut across the point of the lap lengthwise of the sample. For double belting the test shall be made on the single ply.

(b) PERCENTAGE ELONGATION.—*Elongation.*—The average elongation at a tensile stress of 2,500 pounds per square inch shall not exceed 15 per cent. The average shall be determined with the same five test specimens used for determining the tensile strength.

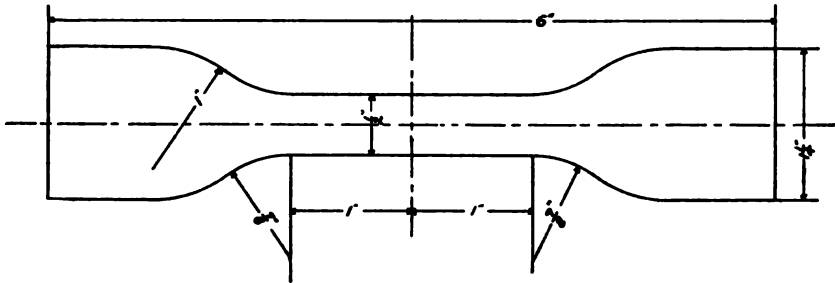


FIG. 1.—Test specimen for strength and elongation.

To determine the amount of elongation, parallel gauge marks 2 inches apart shall be placed upon the restricted portion of the test specimens. The distance between the gauge marks shall be measured with a pair of spring dividers at a tensile stress of 2,500 pounds per square inch. The amount of stretch shall then be determined by measuring the opening of the dividers on a scale. This test will be made on each lot of 2,000 feet or fraction thereof.

The following stretch test shall be made on the finished belting up to and including 6 inches in width. Any section of a roll or belt shall be selected (which shall not be cut) on which gauge marks shall be placed 10 feet apart. Suitable clamps shall be attached on the marks so that the distance between the clamps shall be 10 feet. The section shall then be suspended in a vertical position from one of the clamps. Sufficient weight, including the weight of the clamps, shall be attached to the lower clamp to produce a tensile stress of 750 pounds per square inch of the average cross section of the section being tested. The section, after being subjected to this tension for 15 minutes, shall show a

length between the gauge marks not to exceed 10 feet 7.2 inches (6 per cent stretch).

*Measure of elasticity.*—The clamps shall then be removed, and the section allowed to lie loosely on the floor for 17 hours, after which time the length between the gauge marks shall not exceed 10 feet 1.6 inches ( $1\frac{1}{3}$  per cent stretch).

(c) **CRACKING.**—The leather shall not crack on the grain side and the laps shall not open at the points when the belting is bent through angles of  $180^\circ$ , grain side out, over forms as specified below for the different grades and thicknesses.

TABLE 4.—Forms for Cracking Test.

Belt.	Average thickness, belting.	Diameter form.
	Inches.	Inches.
Single.....	Under 10/64.....	1
	10/64 and over.....	1½
Double.....	Up to 17/64.....	3
	19/64 and over.....	4

(d) **PIPING.**—The leather shall not show wrinkles on the grain side (commonly called piping and indicating looseness of fiber found in side stock or second-quality belting) when bent through an angle of  $180^\circ$ , grain side in, over forms as specified below for the different grades and thicknesses.

TABLE 5.—Forms for Piping Test.

Belt.	Average thickness, belting.	Diameter form.
	Inches.	Inches.
Single.....	All.....	2
Double.....	Up to 17/64.....	4
	19/64 and over.....	6

(e) **WATER ABSORPTION TEST.**—A sample waterproof dressed or waterproof belting, 12 inches long shall be weighed and then immersed in water at room temperature for five hours. When removed from the water the sample shall be wiped and again weighed. The percentage of water absorbed shall not exceed 8 per cent. This test shall be made on every lot of 2,000 feet or fraction thereof.

(f) **TESTING OF WATERPROOF CEMENT.**—The sample of waterproof belting tested for water absorption shall be again immersed in water until the total period of immersion is 24 hours. The sample, after removal, shall be allowed to dry under room con-

ditions for 24 hours. The laps and plies shall not open when the sample is bent around the proper form as specified in paragraph (c) "Cracking."

## 2. CHEMICAL TESTS.

(a) **METHODS.**—The chemical analysis shall be made in accordance with the standard methods of the American Leather Chemists' Association, and percentages calculated on the basis of moisture-free leather.

(b) **STUFFING CONTENT.**—The stuffing content shall not exceed 18 per cent nor be less than 8 per cent of the weight of the finished leather. The currying mixture shall not contain more than 35 per cent of unsaponifiable matter. In the case of belting that has been waterproof dressed, the grease content shall not exceed 25 per cent, and the unsaponifiable matter shall not exceed 35 per cent.

(c) **ASH.**—The total ash shall not exceed 1 per cent of the weight of the finished leather.

(d) **FREE MINERAL ACID.**—The free mineral acid shall not exceed three-fourths of 1 per cent.

(e) **GLUCOSE.**—Glucose resulting from the tanning materials shall not exceed 2 per cent.

(f) **SAMPLES.**—A representative sample from each size of all shipments of 2,000 feet, or fraction thereof, 36-inch length and including at least one lap, shall be selected by the Government inspector for physical and chemical tests.

## IV. GENERAL.

### 1. REQUEST FOR BIDS.

When bids are requested, the buyer shall specify the ply, length, width, and grade desired on each item, and if the belting shall be waterproof dressed or waterproof belting, it shall be so stated.

### 2. PACKING, MARKING, AND SHIPPING.

Unless otherwise specified, the belting shall be packed in accordance with the standard practice of the manufacturer. It shall be marked:

Name of contractor.

Type and size of belting.

Contract number.

Requisition number or schedule number.

The belting shall be shipped in accordance with the instructions of the purchaser.

(a) **INSPECTION.**—All inspections shall be at point of manufacture wherever possible, but the Government reserves the right to inspect at point of delivery, in which case material, if rejected, shall be removed by contractor at his own expense.

### 3. METHODS FOR CHEMICAL ANALYSIS.

(a) **PREPARATION OF SAMPLE.**—The sample of leather for analysis shall be reduced to as fine a state of division as practicable, either by cutting or grinding.

(b) **MOISTURE.**—Dry 10 g of leather for 16 hours at a temperature between 95–100° C.

(c) **FATS.**—Extract 5 to 10 g of air-dry leather in a Soxhlet apparatus until free from grease, using petroleum ether boiling below 80° C. Evaporate off ether, and dry to approximately constant weight.

(d) **ASH.**—Incinerate 10 to 15 g of leather in a tared dish at a dull, red heat until carbon is consumed. If it is difficult to burn off all the carbon, treat the ash with hot water, filter through an ashless filter, ignite filter and residue. Add the filtrate, evaporate to dryness, and ignite.

(e) **WATER-SOLUBLE MATERIAL.**—Digest 30 g of leather in a percolator over night, then extract with water at 50° C. for three hours. The total volume of solution to be 2 liters.

(f) **GLUCOSE.**—Place 200 cc of leather extract of analytical strength in a ½-liter flask, add 25 cc of a saturated solution of normal lead acetate, shake frequently (5–10 minutes), and filter. (The funnels and beakers must be kept covered to prevent evaporation.) Add to the filtrate an excess of solid potassium oxalate. Mix frequently for 15 minutes and filter, returning the filtrate until clear. Pipette 150 cc of this filtrate into a 600 cc Erlenmeyer flask, add 5 cc of concentrated HCL, and boil under a reflux condenser for two hours. Cool, neutralize (place a small piece of litmus paper in the flask) with anhydrous sodium carbonate, transfer to a 200 cc graduated flask, and make to volume. Filter through a double filter. (Filtrate must be clear.) Determine the dextrose immediately in 500 cc of the solution according to the Munson and Walker method,<sup>1</sup> and report in percentage on leather.

<sup>1</sup> This method may be found in the following references: J. A. C. S., 28, pp. 663–686; 1906; Bureau of Chemistry Bulletin 107; Methods of Analysis of the A. O. A. C., 1920 edition; and A. I. C. A. Methods of Analysis for Vegetable Tanned Leather; 1921.

(g) **FREE MINERAL ACID, PROCTOR AND SEARLE METHOD.**—Moisten 2 or 3 g of the leather in a platinum basin with 25 cc N/10  $\text{Na}_2\text{CO}_3$ , and evaporate to dryness on the water bath. The mass is carbonized at a dull, red heat, pulverized with a glass rod, and washed out with boiling water, the soluble portion being filtered through a quantitative filter paper into a conical flask. The insoluble portion in the filter paper is returned to the basin, ignited thoroughly, the ash taken up with 25 cc N/10 HCL, and added to the portion previously washed out. The solution is titrated back with N/10 alkali, using methyl red or methyl orange as indicator, and the amount calculated to mineral acid as sulphuric. If the solution is alkaline no further titration is necessary.

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DEPARTMENT OF COMMERCE

BUREAU OF STANDARDS

George K. Burgess, Director

**CIRCULAR OF THE BUREAU OF STANDARDS, No. 149**

# **A STANDARDIZED METHOD OF MEASURING THE SIZE OF HOSIERY**

**FEBRUARY 1, 1924.**



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## A STANDARDIZED METHOD OF MEASURING THE SIZE OF HOSIERY.

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### ABSTRACT.

As a result of cooperation of the National Association of Hosiery and Underwear Manufacturers, methods of measuring the size of hosiery were investigated, and a standard method based on the suggestions of the Bureau of Standards was selected by a committee of manufacturers. Inquiries to a number of manufacturers and users brought out the fact that no large class of them used the same method of measuring. This resulted in a great confusion of marked sizes on hosiery. The standard method described in this paper has been adopted by the manufacturers, and the Government departments through the Federal Specifications Board, and is being introduced to the retailers and consumers.

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The lack of standardization in the textile industry is forcibly evidenced by the failure of the hosiery interests to observe the advantages to be obtained by developing and adopting universally some standard method for measuring hosiery. A consumer using one particular size of hosiery from one manufacturer changing to the same marked size of a different brand might be subjected to discomfort resulting from misfitted hosiery, because of the difference in actual size resulting from a difference in method of measuring. The wearing qualities of the material will probably be affected, for if the hosiery is too small, the pressure of the foot combined with abrasion will cause frequent ruptures at the toe or heel.

This apparent lack of a standard method of measuring the size of hosiery or of a definition of what is meant by the size of hosiery caused the National Association of Hosiery and Underwear Manufacturers to send out a number of questionnaires to some of the largest manufacturers in order to ascertain the existing methods of measuring. It was the intent of that association to develop a standard nomenclature of size in order to obviate the uncertainty that exists in the designation of hosiery sizes. This association asked the cooperation of the Bureau of Standards, the latter serving in this development in studying and analyzing the different methods found and suggesting one method which could be considered for adoption by the manufacturers' committee.

The "size of hosiery" is an accepted trade term, and for circular knit hosiery is the measured distance in inches between two

points of the toe and heel, measured in a straight line. The differences in practice, however, resulted from nonuniformity of the position of this line in connecting the toe and the heel.

In attempting to find the various methods of measuring now employed, the following questionnaire was sent out by J. N.

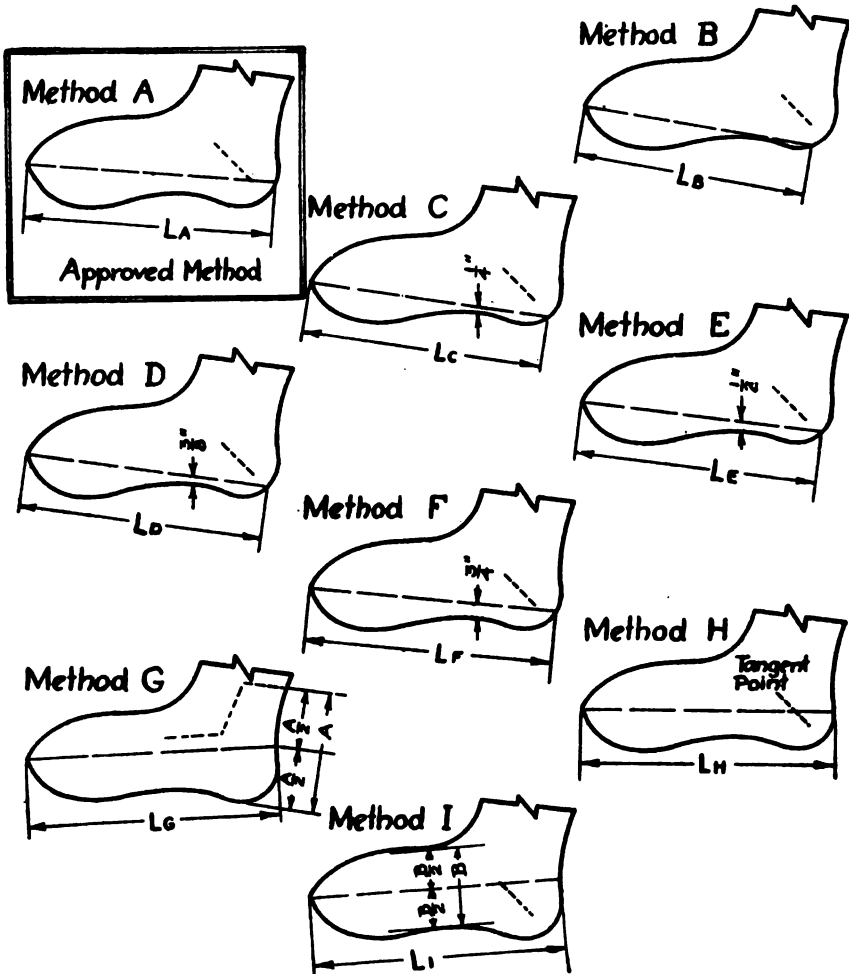


FIG. 1.—Methods used in measuring the size of hosiery by nine different manufacturers.

Method A is now the approved practice.

McCullaugh, national secretary and consulting industrial manager of the association.

This office has started to work with the Bureau of Standards on subjects of research and standardization in Washington. There is no doubt that there are many things existing in this industry, as well as in all others, that are the result of practice rather than careful thought and attention. We are all more or less prone to accept industrial

inheritances, without profound investigation, if these inheritances can be classified as "trade practice." The writer has had occasion to question several manufacturers as to the method of measuring hosiery. He has found at the present time that there are four different standards used by the various manufacturers to measure the size of a foot. It seems to me that this is one of the primary conditions that should be corrected through your association; that is, let us arrive at a standard method of measuring, and from there we can build up, I believe, into many things.

Will you please send to this office at your earliest possible convenience your standard method of measuring, in order that we may make a comparison and form deductions from it.

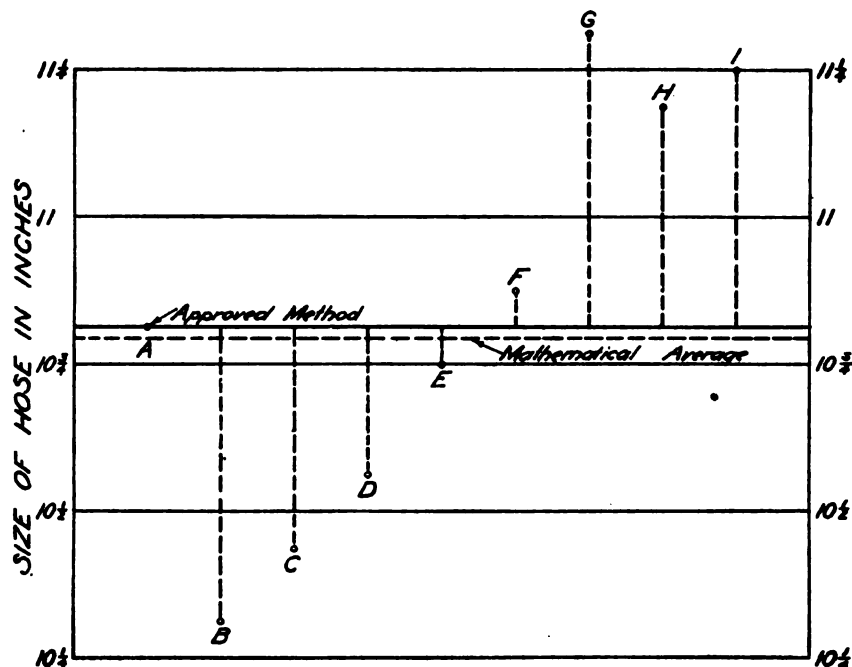


FIG. 2.—Variation from approved method A in the results from eight other existing methods of measuring one selected specimen of hosiery.

From the replies received it was found that nine different systems of measuring circular knit hosiery were in use. Figure 1 shows methods A to H, inclusive, each varying in the resultant length of line drawn from tip of toe to a point along the back of the heel, when the stocking is laid in a flat position. (In applying these different systems to a single selected hose, measurements were made and found to vary more than 1 inch.) One inch difference in length is interpreted as one size difference.

From Figure 2, in which the resultant length of hose produced by each method is plotted vertically over the different systems, a variation between measurement and marked size was found of  $11\frac{1}{8}$  to a minimum of  $10\frac{1}{8}$ . This could be interpreted as mean-

ing that for one particular hose one manufacturer would perhaps label it size 10, another size 11, and still another  $10\frac{1}{2}$ . The lengths of hose were measured to the nearest one-sixteenth of an inch. Accordingly, it will be found that the lengths of stocking do not fall exactly on the standard sizes manufactured. For men's hosiery, these standard sizes are  $9\frac{1}{2}$ , 10,  $10\frac{1}{2}$ , 11,  $11\frac{1}{2}$ , and 12; for women's hosiery, 8,  $8\frac{1}{2}$ , 9,  $9\frac{1}{2}$ , 10, and  $10\frac{1}{2}$ . With the existing practices it is possible that by systems B and C of Figure 2 hosiery would be called size 10; by methods D, E, A, and F, size  $10\frac{1}{2}$ ; while by methods G, H, and I, it would be classed as size 11. This, however, is not always true, as some manufacturers purposely make what would be termed and measured a size  $10\frac{1}{2}$ —that is,  $10\frac{1}{2}$  inches long by, say, method A—but still mark the goods size 10 for the purpose of giving extra length and accordingly, as they believe, extra service and comfort. This is an exception to the general marking practice.

After this survey was made, the report was rendered to the manufacturers' committee, composed of J. N. McCullaugh, national secretary and industrial manager of the National Association of Hosiery and Underwear Manufacturers; J. H. Zens, president of the National Association of Hosiery and Underwear Manufacturers; W. W. Moyer, president of W. W. Moyer Co.; and S. D. Bauscher, president of S. D. Bauscher & Son (Inc.). As a result of their consideration, method A was approved as standard. This selection was made from two points of reasoning: (First, that method A is approximately equal to the numerical average of all nine systems; that is, the average of the dimensions of all systems on the same hose; second, from a consideration of the most consistent points in the foot of the hosiery in respect to its manufacturing construction. This latter point involved a consideration of the points which are included in the different shapes of hosiery forms and of the practices which are employed in the constructions of the heel and toe, including the ratio of needles dropped and needles employed in constructing the heel and toe, and also including the length of the gore in terms of the number of stitches. This necessitates that the heel gore be always a certain proportionate distance from the curve of the heel toward the bottom of the foot. In boarding the stocking, care is taken to have the gores run parallel to each other. (These two points were found to be the tip of the toe and the lower part of the heel gore. These points were decided upon by consensus of opinion of several experts and the committee.

The method of measuring the size of circular knit hosiery by method A may be defined as follows: After the hose has been boarded and pressed and appears in a flat and unwrinkled condition, place a ruler along a line in which the tip of the toe and the bottom of the heel gore are connected. The measured distance along this line from tip of toe to the intersection with the back of the heel to the nearest half inch is the hosiery size. Preference should be given to the lower number; that is, if the exact measurement, as found by the system, is  $10\frac{1}{4}$  inches exactly, it is desirable to call the stocking size 10.

Figure 3 is a diagram showing application of ruler between the points selected denoting size.

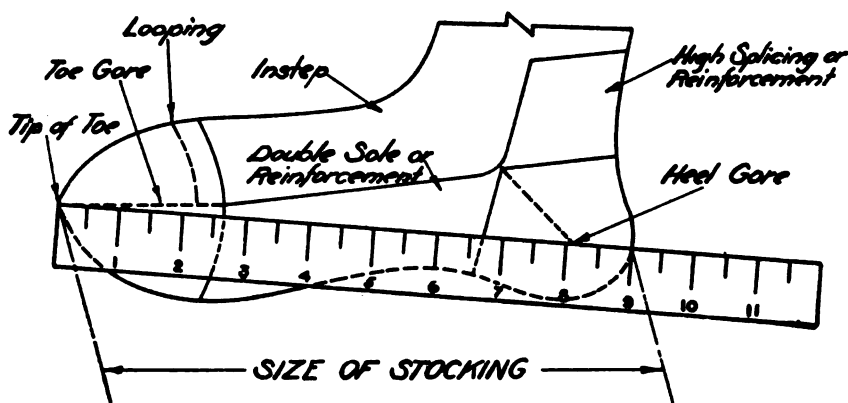


FIG. 3.—Approved method for measuring hosiery.

This diagram shows the application of ruler to the hosiery.

The development of a standard method of measuring hosiery, as described in this circular, is the first attempt known to the writers to standardize the method of measurement. It has resulted in a general adoption, and having been introduced about six months ago is very widely used to-day. The following associations have adopted this standard method: The National Association of Hosiery and Underwear Manufacturers, comprising a very large per cent of the hosiery manufacturers; the Federal Specification Board, representing the Government, one of the largest users of textiles; the American Home Economics Association, who will be very valuable in familiarizing the public with this method of measurement; and the Bureau of Standards, which has recorded this standard as a trade practice.



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**DEPARTMENT OF COMMERCE.**

**U.S. BUREAU OF STANDARDS.**

**" George K. Burgess, Director.**

**CIRCULAR OF THE BUREAU OF STANDARDS, No. 150.**

[December 28, 1923.]

**RECOMMENDED SPECIFICATION FOR QUICKLIME AND  
HYDRATED LIME FOR USE IN THE MANUFACTURE  
OF SAND-LIME BRICK.**

This is the sixth of a series of specifications for the lime used in various chemical industries. To assist in the development of these specifications the bureau has called together an Interdepartmental Conference on Chemical Lime, composed of representatives of the Geological Survey and Bureau of Mines of the Interior Department; the Bureau of Soils, Bureau of Chemistry, Forest Service, and Fixed Nitrogen Research Laboratory of the Department of Agriculture; and the Chemical Warfare Service of the War Department. The present specification, based on a draft originally prepared by W. E. Emley of the lime section, Bureau of Standards, has been unanimously approved by the above conference and by the National Lime Association.

**ABSTRACT.**

Sand-lime brick is made of sand bound together with lime. The lime is caused to combine chemically with some of the sand by treatment with high-pressure steam. Lime for this purpose must be completely hydrated and must be reasonably free from magnesia and carbon dioxide. About 85 per cent purity is required.

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### 1. GENERAL.

(a) **USE OF LIME IN MAKING SAND-LIME BRICK.**—Sand-lime brick is made by mixing sand and lime, pressing the mixture into brick form, and curing with high-pressure steam. The steam causes a chemical reaction to occur between the lime and sand, forming what is believed to be a hydrated calcium silicate. This silicate acts as a binding material to hold together the excess sand, which forms the major portion of the brick.

The lime must be completely hydrated before it is mixed with the sand and made into brick. Otherwise, subsequent hydration is apt to weaken or disrupt the brick. Overburned lime or magnesia may cause trouble because they hydrate slowly.

Most manufacturers of sand-lime brick prefer, for economical reasons, to buy quicklime and make their own hydrate. Others buy commercial hydrated lime.

(b) **DEFINITIONS.**—Quicklime is the product resulting from the calcination of limestone and consists essentially of calcium oxide, or of calcium and magnesium oxides. It will slake when water is added to it, and this slaking is accompanied by an evolution of heat and an increase in volume. Hydrated lime is a dry powder which is made by treating quicklime with enough water to satisfy its chemical affinity under the conditions of manufacture. It consists essentially of calcium hydroxide, or of a mixture of calcium hydroxide and magnesium oxide or hydroxide.

(c) **PACKING.**—Quick lime is shipped either in bulk in carload lots or barrels holding 180 pounds net or 280 pounds net each. Hydrated lime is shipped in paper bags holding 50 pounds net each.

### 2. REQUIREMENTS.

(a) **QUALITY.**—Quicklime must be of such a nature that it will slake freely and completely. It must, therefore, be free from ashes, clinker, fused silicates, and similar visible impurities. Hydrated lime must be completely hydrated. Such chemical impurities as silica, iron, and alumina may be regarded merely as diluents, except when they are fused with the lime to form slowly slaking compounds.

(b) **COMPOSITION.**—Quicklime or hydrated lime shall contain not less than 85 per cent calcium oxide nor more than 5 per cent magnesium oxide, both figures being based on the nonvolatile portion of the material.

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*Specification for Lime and Sand-Lime Brick.*

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The carbon dioxide in the quicklime as received shall not be more than 5 per cent. The carbon dioxide in the hydrated lime as received shall not be more than 7 per cent.

Hydrated lime shall contain sufficient water to meet the chemical requirements of the calcium oxide.

(c) **MARKING.**—Each carload of material, or fraction thereof, shall be legibly marked with the names of the consignor and consignee, and with some means of identifying the particular contract on which the shipment is made.

This information is in addition to that required by the Federal lime-barrel law.

(d) **RETESTING.**—Notice of the rejection of a shipment based on these specifications must be in the hands of the consignor within 10 days after the receipt of the shipment at the point of destination. If the consignor desires a retest, he shall notify the consignee within five days of receipt of the notice of rejection. The consignee shall provide all reasonable facilities to permit the consignor to resample the material. This retest shall be at the expense of the consignor.

**3. SAMPLING AND TESTING.**

(a) **SAMPLING.**—The purchaser shall bear all expense of sampling and testing. When quicklime is shipped in bulk, the sample shall be so taken that it will represent an average of all parts of the shipment from top to bottom, and shall not contain a disproportionate share of the top and bottom layers, which are most subject to changes. The sample shall consist of 1 shovelful for each 3 tons of material, but not less than 10 shovelfuls, taken from different parts of the shipment. The total sample taken shall weigh at least 100 pounds, shall be mixed thoroughly, and "quartered" to provide a 15-pound sample for the laboratory. In case a shipment consists of more than one car, a separate sample shall be taken from each car.

When quicklime is shipped in barrels, at least 3 per cent of the number of barrels shall be sampled. They shall be taken from various parts of the shipment, dumped, mixed, and sampled as specified in the above paragraph.

In the case of hydrated lime, the sample shall be a fair average of the shipment. Three per cent of the packages shall be sampled. The sample shall be taken from the surface to the center of the package. The material so obtained shall be thoroughly mixed and quartered to provide a 2-pound sample for the laboratory.

When sampling quicklime or hydrated lime, it is essential that the operation be conducted as expeditiously as possible, in order to avoid undue exposure of the material to the air. The sample to be sent to the laboratory shall immediately be placed in an air-tight container in which the unused portion shall be stored until the shipment has been finally accepted or rejected by the purchaser.

The sample may be taken either at the point of shipment or at the point of destination, as agreed upon by the contracting parties.

(b) TESTING.—The following directions for analytical work are taken from American Society for Testing Materials, Tentative Methods of Chemical Analysis of Limestone, Quicklime, and Hydrated Lime, C25-22T. For further information on this subject, reference should be made to "The analysis of silicate and carbonate rocks," by W. F. Hillebrand, U. S. Geological Survey, Bulletin No. 700.

Weigh out 0.5 g of the substance and, if hydrated lime, ignite in a covered platinum crucible in an electric muffle for 15 minutes, or longer if the heat is not powerful enough to effect complete decomposition within that time. Transfer to an evaporating dish, preferably of platinum for the sake of celerity in evaporation, mix to a thin slurry with distilled water, add 5 to 10 cc of HCl (sp. gr. 1.20) and digest with aid of gentle heat and agitation until solution is complete. Solution may be aided and the time shortened by light pressure with the flattened end of a glass rod upon resistant lumps. Then evaporate the solution to dryness, so far as this may be possible on the water bath.

When dry or nearly so, place the dish and its contents in an air bath or (covered) on a platinum triangle resting on a hot plate. Drench the cooled mass with HCl (sp. gr. 1.20) and allow to stand for a few minutes. Add an equal volume of water, cover the dish, and place on the water bath for 10 minutes. Separate the silica by filtration on a filter of suitable size. Wash thoroughly with dilute HCl and then wash twice with cold water.

Evaporate the filtrate to dryness. Extract the residue with HCl as before, but allowing only a few minutes time. Filter this solution through a second and smaller paper.

Transfer, wet, the papers containing the separated residue to a platinum crucible. Char carefully without allowing the paper to inflame and ignite in an electric muffle and weigh. Correct the silica for foreign matter by evaporating with 5 cc of HF and one or two drops of  $\text{H}_2\text{SO}_4$ . Heat the residue for two or three minutes in an electric muffle.

Fuse the residue from the silica determination using a little  $\text{Na}_2\text{CO}_3$ . Dissolve the cooled melt in HCl and add the solution to the filtrate from the second evaporation for silica. Add a few drops of bromine water or  $\text{HNO}_3$  and boil the solution until all trace of bromine or chlorine is gone. Then add HCl, if not already present, sufficient to insure a total volume of 10 to 15 cc of HCl (sp. gr. 1.20). Add a few drops of methyl red solution, and after diluting to 200 to 250 cc, heat the liquid to boiling. Neutralize by means of  $\text{NH}_4\text{OH}$  (dilute toward the end) until the color of the liquid changes to a distinct yellow. Boil for one or two minutes, allow to settle, filter and wash the precipitate at once two or three times with hot  $\text{NH}_4\text{Cl}$  (2 per cent) solution, and suck dry.

Set the filtrate aside. Dissolve any precipitate from the paper in hot, dilute HCl, the solution passing into the beaker in which the precipitation was made and wash the

paper thoroughly with hot water. Boil the solution to expel any trace of chlorine and again precipitate the hydroxides with  $\text{NH}_4\text{OH}$  as described above.

Add a few drops of  $\text{NH}_4\text{OH}$  to the combined filtrate from the  $\text{R}_2\text{O}_3$  precipitate, and bring the solution to boiling. To the boiling solution add 35 cc of a saturated solution of  $(\text{NH}_4)_2\text{C}_2\text{O}_4$ , and continue the boiling until the precipitated  $\text{CaC}_2\text{O}_4$  assumes a granular form; then allow it to stand 20 minutes, or until the precipitate has settled and the supernatant liquid is clear, filter and wash thoroughly with boiling water. Place the wet filter and precipitate in a platinum crucible, and burn off the paper over the small flame of a Bunsen burner, or in a muffle. Ignite the residue, dissolve in hot dilute  $\text{HCl}$ , and make up the volume of the solution to 100 cc with water. Add  $\text{NH}_4\text{OH}$  in slight excess and boil the liquid. If a small amount of  $\text{Al}_2(\text{OH})_6$  separates, filter it out, wash with  $\text{NH}_4\text{Cl}$  (2 per cent solution), ignite, weigh, and add this weight to that found in the first determination. Then reprecipitate the lime by  $(\text{NH}_4)_2\text{C}_2\text{O}_4$ , allow to stand until settled, filter, wash thoroughly with boiling water, and weigh as calcium oxide after ignition to constant weight in a covered platinum crucible.

Acidify the combined filtrates from the calcium precipitates with  $\text{HCl}$  and concentrate on the water bath to about 150 cc, and heat to boiling. To the boiling solution add 10 cc of a saturated solution of  $\text{Na}(\text{NH}_4)\text{HPO}_4$  and continue the boiling for several minutes. Then cool to room temperature, and add  $\text{NH}_4\text{OH}$  drop by drop with constant stirring until the crystalline ammonium-magnesium orthophosphate begins to form and then in moderate excess, the stirring being continued for several minutes. Allow the liquid to stand in a cool atmosphere for from 12 to 48 hours and filter.

Dissolve the precipitate in hot dilute  $\text{HCl}$ , make up the solution with water to about 100 cc, add 1 cc of the saturated solution of  $\text{Na}(\text{NH}_4)\text{HPO}_4$  and  $\text{NH}_4\text{OH}$  drop by drop with constant stirring until the precipitate is again formed as above described and the ammonia is present in moderate excess. Then allow it to stand in a cool atmosphere for from 12 to 48 hours, filter on paper or a Gooch crucible, wash with dilute  $\text{NH}_4\text{OH}$  containing  $\text{NH}_4\text{NO}_3$ , ignite, cool, and weigh as  $\text{Mg}_2\text{P}_2\text{O}_7$ .

Place 1 g of the properly prepared sample in a weighed platinum crucible, cover with the lid and heat gently for 5 minutes, gradually increasing the temperature to the maximum of the muffle, and maintain at this temperature until constant weight is obtained (usually about 15 minutes).

Carbon dioxide is to be determined upon the properly prepared sample according to the method given in U. S. Geological Survey Bulletin No. 700, page 217. An illustration showing the arrangement of the component parts of the necessary apparatus is shown on page 218 of that bulletin.

Boil the 5 g sample with dilute  $\text{HCl}$  in a small Erlenmeyer flask attached to an upwardly inclined condenser, whence, after passing through a drying system—calcium chloride, anhydrous copper sulphate to retain hydrogen sulphide from decomposable sulphides and any  $\text{HCl}$  that may pass over, then calcium chloride again—carbon dioxide is caught by absorption tubes filled with soda lime followed by calcium chloride. Of course, arrangement is made for a current of air free from  $\text{CO}_2$  with which to sweep out the apparatus before and after the experiment and for a slow current during its continuance.

The manipulations are as follows: Pour hot water upon the powder in the flask fitted with a separatory funnel and delivery tube; attach this to the condenser, and force a current of air free from  $\text{CO}_2$  through the whole system, except the weighed absorption tubes, until the original air has been displaced, the observation bulbs (containing  $\text{H}_2\text{SO}_4$  to show the rate of gas flow) being attached directly to the drying system. Then close the stopcock in the separatory funnel, half fill the latter with  $\text{HCl}$  (1 : 1), replace the rubber stopper of the funnel, insert the absorption tubes between the drying system and the observation bulbs, and allow the acid to flow into

the flask, slowly if there is much carbon dioxide, rapidly if there is but little. When effervescence diminishes in the former case, at once in the latter, light the burner under the flask and start the flow of water through the condenser. Keep the flame low, so as to secure steady but quiet ebullition, and do not interrupt the air current although it should be reduced to a slow rate. With much carbon dioxide the rate of absorption is very readily noted by holding the hand to the soda-lime tubes, which become hot or warm when the absorption is taking place. Sufficient time having elapsed, extinguish the flame, and increase the air current. When cool, disconnect the soda-lime tubes from the apparatus and allow to stand in the balance case until two weights taken 30 minutes apart agree within 0.5 mg.

The soda lime for use in this determination must be porous, not hard and unabsorptive like that sometimes used for the combustion of nitrogenous organic substances.

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